INTERNATIONAL WORKSHOP ON OFFSHORE GEOLOGIC CO_2 STORAGE

Report: 2016/TR2

May 2016

INTERNATIONAL ENERGY AGENCY

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DISCLAIMER AND ACKNOWLEDGEMENTS

IEAGHG supports and operates a number of international research networks and workshops. This report presents the results of a workshop. The report was prepared by IEAGHG and the Bureau of Economic Geology as a record of the events of that workshop.

The International Workshop on Offshore Geologic CO_2 Storage was organised by the Bureau of Economic Geology (BEG) Gulf Coast Carbon Center (GCCC) at the University of Texas in Austin and IEAGHG, in co-operation with the South African National Energy Development Institute (SANEDI). The organisers acknowledge the financial support provided by the Carbon Sequestration Leadership Forum (CSLF), GCCC, and the Climate Technology Centre and Network (CTCN) for this meeting and the hospitality provided by the hosts at the BEG.

An International Steering Committee was formed to develop the technical programme for this workshop. The steering committee members are:

Tim Dixon, IEAGHG (Chair)
Katherine Romanak, BEG (Co-Chair, Host)
Susan Hovorka, BEG (Host)
Tip Meckel, BEG (Host)
Anthony Surridge, SANEDI (Host)
Mark Ackiewicz, US DOE
Di Zhou, China Academy of Sciences
Filip Neele, TNO
Paulo Negrais Seabra- Independent Consultant (formerly Petrobras)
Ryozo Tanaka, RITE

Owain Tucker, Shell
Philip Ringrose, Statoil

Acknowledgements are also given to Jennifer Edwards (BEG) for event support and to Juli Berwald (BEG) for assistance in drafting this meeting report. The report was edited by Tim Dixon and Katherine Romanak.

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Further information or copies of the report can be obtained by contacting IEAGHG at:

IEAGHG, Pure Offices, Cheltenham Office Park,
Hatherley Lane, Cheltenham,
GLOS., GL51 6SH, UK
Tel: +44(0) 1242 802911
E-mail: mail@ieaghg.org
Internet: www.ieaghg.org

International Workshop on Offshore Geologic CO_2 Storage

Meeting Report

Date and location:
April 19-21, 2016, Bureau of Economic Geology, Gulf Coast Carbon Center, The University of Texas at Austin, Austin, Texas, USA.

Hosted by:
Bureau of Economic Geology, Gulf Coast Carbon Center

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Bureau of Economic Geology, Gulf Coast Carbon Center
Carbon Sequestration Leadership Forum,
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IEA Greenhouse Gas R&D Programme
Climate Technology Centre and Network

Report Contents:

Executive Summary

The world of offshore CCS gathered together 19-21 April, 2016 at the Bureau of Economic Geology (BEG) at The University of Texas, Austin, Texas, USA for a workshop on offshore geological CO_2 storage. The workshop was organized by the Gulf Coast Carbon Center at BEG, IEAGHG, and the South African National Energy Development Institute, and was supported by the Carbon Sequestration Leadership Forum (CSLF). Over 50 people attended from 13 countries, including from seven developing countries.

The workshop was organized in response to a recommendation for international knowledge-sharing outlined in the CSLF Final Report on Technical Barriers and R&D Opportunities for Offshore, Sub-Seabed Storage of CO_2 which was finalized in September, 2015 (http://www.cslforum.org/publications/documents/OffshoreStorageTaskForce_FinalCombinedReport.pdf)

The aims of the workshop were to undertake a global needs assessment for offshore geological CO_2 storage, to initiate a discussion about the various aspects of offshore transport and storage, and to build an international community of parties interested in offshore storage. This was achieved by bringing together those who are doing offshore CCS to share knowledge with those who are interested in doing, and by facilitating countries to identify their specific issues, challenges, opportunities, and then to identify synergies, common gaps and goals, and define common action items. There was a pre-workshop survey to assess the status and needs assessment survey for each country.

Experts shared their knowledge and experiences on the first day, with the current state of knowledge from Norway (Statoil), The Netherlands (TNO), Brazil, Japan (RITE), and the UK (Shell). These "How To…." talks covered storage assessments, CO_2-EOR, transport options, risk management, monitoring, environmental impacts, infrastructure and regulations. Of particular interest were the subsea engineering solutions being developed by Aker Solutions to take gas-processing systems off the platforms and onto the seabed, and the potential for shipping with hubs.

Other countries then presented their status and needs, including South Africa, China, USA, Nigeria, Ghana, Korea, Mexico, and Australia. Information was also provided on the Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP) initiative and the CGS Baltic programme, both undertaking regional storage assessments. It was notable that although each country is in very different stages of pursuing offshore CCS, these countries also share common interests as outlined in this report.

Participants formed breakout groups to discuss issues around themes identified by the workshop, including technology transfer, infrastructure, funding and finance, moving from pilot to larger-scale projects, and regulations. This activity resulted in development of a list of recommendations on areas to be addressed and actions to be taken. Common issues included how to assess storage potential, and the many aspects of re-use of existing offshore infrastructure.

In summary, the list of recommendations included:

- International collaboration and funding mechanism for a demonstration project.
- Development of a test programme and pilot project for infrastructure developments.
- Workshops and training on a range of topics including: storage resource assessment, funding sources for early stages of CCS resource assessment in developing countries, platform infrastructure and transport infrastructure issues and developments, and comparing specific aspects across projects such as environmental monitoring.
- Assistance with access to existing key information sources, and a common language on storage.
- Creation of an 'Offshore Network' or other means of continuing the momentum from this workshop.

The workshop concluded with demonstrations and posters of offshore work featuring several of US DOE's recently funded studies, and included a demonstration of the P-cable monitoring system and its results from the Gulf of Mexico.

Of note was that the UNFCCC's Climate Technology Centre and Network (CTCN) supported attendees from Nigeria and Ghana, and this was possibly the first activity on CCS supported by CTCN. There was great interest from all the developing country attendees in the CTCN (IEAGHG and The University of Texas are members of the Network) and a separate session was devoted to introducing developing countries to the work of the CTCN.

Overall, it was clear that each country is at a different stage on the path to offshore CCS, but with common interests. The enthusiasm from attendees suggested they considered the workshop a success. There was common recognition that there is a nexus of interests and needs converging in progressing CCS offshore, and that momentum was being created towards international collaboration, not just in knowledge-sharing, but towards pilot and demonstration projects.

Figure 1. Attendees at the International Workshop on Offshore Geologic CO_2 Storage

The PowerPoints of the talks and the posters are posted on the GCCC website at http://www.beg.utexas.edu/gccc/goi.php

Goals and Objectives

The goal of this workshop was to facilitate a global needs assessment for offshore geological CO_2 storage. To achieve this, the specific objectives were to initiate a discussion about the various aspects of offshore transport and storage, and to build an international community of parties interested in offshore storage. This process would facilitate countries to identify their specific issues, challenges, opportunities, etc. The overall exercise was intended to identify synergies, common gaps and goals, and define common action items. There was a pre-workshop activity of a survey of status and needs assessment survey for each country.

Introduction Session

Figure 2. Scott Tinker, Director of the BEG giving welcome and opening remarks

Scott Tinker Director, Bureau of Economic Geology (BEG), the University of Texas at Austin.

Scott gave a formal welcome to the Bureau of Economic Geology. The Bureau is situated in what might be called the radical middle, an intersection of academic (NGO), governmental, and industrial institutions. It's a place that includes a permanent staff of 25 nations and 6 continents, where diversity is important. Similarly, the group assembled for the workshop is extremely diverse, hailing from 6 continents and over two dozen countries. It is also a diverse mix of academic, governmental, and industrial institutions. BEG has a long history with CCS, with CCS projects onshore, and has a number of unique tools for investigating the offshore such as the detailed seismic mapping of the P-cable and nanotechnology developed by the advanced energy consortium. The USDOE has been strong partner in efforts to understand offshore CCS, as has the international community, such as those represented at this workshop.

Susan Hovorka, Gulf Coast Carbon Center (GCCC), The University of Texas at Austin

The Gulf Coast Carbon Center was established in 2008 with a DOE grant to look at source-sink alignment and onshore reservoir characterization. The project determined that the best place to store carbon is in sediments under continental shelves, the "sand pile at edge of continents." There, the sand sags, there is mud overlay, and thick stacks are formed at edge of every continent. These sediments are young and can accept CO_2. Further, these suitable geological formations are near sources. Placing storage offshore eases public anxiety.

Tony Surridge, South African National Energy Development Institute (SANEDI)

Tony pointed out that smoke used to be symbol of prosperity. After we discovered its health hazards, we enacted anti-smoke rules. They cost money. Today, nobody complains about that price. Then we enacted rules to limit SOx and NOx. These limitations also cost money. Today nobody complains about the price. Now we are faced with the problem of limiting the emission of CO_2. The difference is that it's a global issue not a local issue, which makes regulations more difficult. However, we are here to consider a way to make progress toward that goal. Thank you to CSLF for funding for this meeting.

Tim Dixon, IEAGHG, Tip Meckel, GCCC, Katherine Romanak, GCCC - Workshop goals and expectations

Tim put the workshop into the context of the Paris Agreement from COP-21, which agreed to limit our temperature increase to 2C by end of century, and even more ambitious to pursue 1.5 C. According to the IPCC 5th Assessment Report, reaching these goals becomes more expensive or even impossible if you take CCS out of the equation.

Figure 3. Tim Dixon of IEAGHG speaks about how countries plan to reduce their CO_2 emissions following the 2015 Paris Agreement.

One hundred eighty seven countries submitted plans, called Intended Nationally Determined Contributions (INDCs), to the UNFCCC detailing how they would reduce their carbon emissions. Given those plans, if all enacted would put the world onto a new trajectory to a temperature increase of 2.7C, not enough but better than the current 3.6C. Only 10 INDCs mentioned CCS, but these first ones are looking at short-term actions. There is potential for more countries to adopt CCS, especially if it becomes viable offshore.

At COP-21, IEAGHG and BEG held a side event focused on CCS which included offshore potential. Speakers included BEG, the Premier of Saskatchewan, and the Director of CTCN. The event focused on project experiences. The interest was high and the event was extremely well attended.

Tim noted that on 22 April, 2016, the largest historic gathering of countries would be in New York to sign the climate treaty. There is currently strong political momentum to achieve climate goals, and offshore CCS has a role for many countries, hence this workshop.

Tip described the scope of this meeting as a needs assessment. The aim is to initiate discussion, and there are three major objectives to keep in mind.

1. What is required for offshore CCS
2. To identify specific issues
3. To identify synergies; recommend actions

Katherine thanked the CSLF for their funding, with acknowledgement to Mark Ackiewicz of US DOE, and from the UNFCCC Climate Technology Centre Network (CTCN). This meeting is in a sense historic as it is the first-ever funding by CTCN of a CCS-related activity. Felicia Chinwe Mogo from the Nigerian Maritime Administration and Safety Agency (NIMASA) and Joseph Essandoh-Yeddu from the Energy Commission, Ghana, were supported by CTCN to attend this workshop.

Mark Ackiewicz, U.S. DOE - Overview of CSLF Report on Offshore CCS

Figure 4. Mark Ackiewicz, U.S. DOE, led the CSLF Task Force on Offshore Geologic CO_2 Storage.

Mark introduced the CSLF, which is a ministerial-level organization with a focus on making CCS technologies available, and has 24 countries and the European Commission as members. It is comprised of technology and policy groups. The aims of CSLF are to share information, build capacity, explore financing, and develop global RD&D roadmaps for CCS.

The CSLF Offshore Storage Task Force was established in 2013 after GCCC gave a presentation on the topic in Washington DC. In March 2014, Offshore Storage was adopted as a Task Force and worked to produce the largest report on the Offshore CCS. It involved 31 authors from 7 countries, one multilateral organization, and 4 continents.

The report makes a number of key recommendations. In terms of knowledge sharing, there are few data points and it recommends increasing those by looking for potential areas for collaboration. Capacity assessment is still inadequate on a global basis, and it suggests looking to pre-qualify storage locations through basin evaluation. This will require international collaboration. It is optimistic about transport infrastructure improvements and hopes to take advantage of pilot and demonstration projects to prove them out. Offshore EOR has only one data point, so much remains to be learned. With regard to impacts to subsea, it suggests to leverage activities like QICS which are developing a valuable knowledge base. In terms of monitoring, technologies exist, but the temporal and spatial scale of monitoring still need to be improved.

A copy of the CSLF Offshore Storage Task Force Report can be found at:
http://www.cslforum.org/publications/documents/OffshoreStorageTaskForce_FinalCombinedReport.pdf

Finally, one of the major outcomes of this CSLF Task Force is this workshop. In addition, a CSLF Offshore EOR Task Force report is being developed.

Current State of Knowledge Session

Tip Meckel, BEG - Assessing Offshore Storage on Continental Shelves

Three motivating messages: 1) For CCS to be significant on desired timelines we need 6 GT of storage by 2050, which is equivalent to 6000 Sleipner projects. 2) Two-thirds needs to come from non-OECD countries. 3) There’s an important tie to natural gas and CCS.

“Sweet spots” are places with a good source-sink match, single ownership, youth, sandy, low stress and appropriate thickness. These places allow us to focus on deployment of industrial-scale demonstration projects. We should consider the resource development of gas along with CCS. Much gas is CO_2 rich and requires CO_2 management.

Offshore shelves are the largest gigatonne-scale storage for CCS. Passive margin basins are key and exist throughout the world. Offshore CCS projects can take advantage of these basins.

The first step is usually an atlas, which provides high-level estimates of static capacity. The conclusion from several such atlas projects is that there are very large capacity estimates. In Texas the minimum depth of storage is controlled by conditions that maintain supercritical CO_2. The maximum depth is overpressure. We estimate storage capacity of 172 GT in Texas state waters.

Figure 5. Tip Meckel, BEG, speaks about the first steps towards offshore storage; assessing storage capacity.

A lot of the basins around the world have world-class oil fields and good potential capacity. But it’s important to consider anywhere you find a world-class oil field with a good seal, what makes it so good? Conceptually, the geologic history of basins includes passive rifting, which generates deep crustal faults that infill with younger fluvial deposits. These similarities mean we have similar problems to solve when we consider CCS environments.

A nice metaphor is a flock of ducks: each duck looks different, but none are cats. The similarities of CCS environments include deep rift sequence (CCS basement), regional unconformities, flooding surfaces, basement faults, and overburden growth structures. We should listen to the basins. The basin is trying to tell us what it likes, and we should listen to it.

A most important question that really needs to be understood has to do with rates: do we know enough about how fast we can store carbon dioxide? These engineered scale vs. geologic scale considerations are important.

Our focus needs to be on capacity assessment, knowledge transfer, and deployment of demonstration-scale and industrial-scale projects.

Discussion:

How do we define storage capacity: effective or theoretical?
The Society of Petroleum Engineers will address these questions by planning to create a resource maturation system, a way of classifying people's assessments. Matched capacity is another kind of assessment, for example, which takes into consideration matching a source to a sink. UNECE is also working on CO_2 storage classifications.

Philip Ringrose, Statoil, How to assess options for offshore transport and storage and onshore capture, Norway as a case study

This is the 20th anniversary of Sleipner. It has importance for communicating that CCS works. It's key to point out that one single chromium-steel well has worked for 20 years. At Snohvit, they've had success for 8 years. These projects build confidence in offshore CCS.

A new full-scale CCS project led by Gassnova and the Norwegian government is under development. The CO_2 supply is being evaluated. The possibilities include a waste-to-energy plant, which burns plastic, extracts heat and potentially CO_2; a cement plant; and ammonia production facilities. The plan is to capture and inject over 1 M tons of CO_2 a year for 25 years.

The CO_2 will be transported by ship. The Norwegian entity Gassco has the task of maturing transport options for the project. A pipeline from onshore is also being evaluated.

Statoil is doing a $4M offshore feasibility study for the project, which is due June 1, 2016 and will be made available July 1. Three sites are under consideration, and they are looking for cost-effectiveness. They are evaluating wells, wellhead, monitoring, platform, etc. They are looking at reservoir depth, well design, plume behavior, and risk evaluation. The reference design is 1.3 Mt/year for 25 years. Such a complete study really requires a major oil company.

Ringrose proposed that there are three main barriers to CCS. First, cost is significant. Projects need to integrate with oil and gas infrastructure including EOR to make financial sense. Second, capacity requires managing pressure. Finally, projects need to develop public confidence. The public is always concerned and we need to show that we are monitoring CCS activities.

Snohvit had pressure management fluctuations. Such fluctuations are normal for oil production but possibly not expected for CCS. They used time-lapse seismic for monitoring, which proved cost effective by saving on well operations costs. At Sleipner seismic monitoring data reveals that the CO_2 plume develops as an inverted cone shape, but most ended up flowing in two layers. The flow process is dominated by gravity forces.

Conclusions: The total CO_2 stored in Norway is 20 Mt. We recognized the importance of the learning curve. Norway has an ambition to realize a full-scale CCS facility by 2020.

Discussion:

What is the regulatory support?
In Norway, there is a tax of around $50/ton for CO_2 emissions to atmosphere from industrial sources. This is a major motivator. Also, every injection well is now required to have a down-hole gauge, which makes monitoring more reliable.

How do you ensure sequestration? Does CO_2 react?
Yes, CO_2 does react and we have to have a well that it's resistant to corrosion. Leakage detection is accomplished using CO_2 imaging to show where CO_2 is. We have to satisfy a regulator and this requires open dialog. Abandoned wells are a challenge.

How long will Sleipner continue?
The operational life was 25 years, but now they are bringing on new fields and Sleipner is acting as a hub for other fields.

Vincent Vandeweijer, TNO - How to develop a pilot injection project offshore, history of K12B

K12-B is the first site were CO_2 is re-injected into the same reservoir from which it was withdraw. The actual CO_2 injection began in 2004 and continues without incident. K12-B is a field lab on a productive gas platform providing a basis for long term research by the operator, TNO and other research institutes.

A major part of the storage capacity in Western Europe lies in the North Sea. The Netherlands has clusters of gas fields in the North Sea. One of the crucial elements for CCS in gas fields is timing. Not all the fields are available for storage at the same or most desired moment in time.

The K12-B project began in 2002 with a feasibility study. The project was subsidized by the Dutch Ministry of Economic Affairs and carried out by Gaz de France Production Nederland B.V., the operator is the K12-B platform, and TNO.

The storage reservoir is, at 3900 m under the ground, very deep. The gas reservoir is now almost depleted. The natural gas contains 13% CO_2, so all production wells are already corrosion resistant (Cr13). The CO_2 that is drawn from the natural gas is separated on the platform with an amine process and compressed before it is reinjected. Chemical tracers were used to identify flow paths and break through times. Over the course of a decade more than 100 kt CO_2 have been safely injected. Currently injection continues, where storing more CO_2 at higher rates is possible at K12-B.

One example of a research result was the development of a method for intentional salt plugging, by brine alternating CO_2 injection. This is a novel concept for long-term sealing (http://repository.tudelft.nl/view/tno/uuid%3Ac9f9bc22-f5d8-4805-8fd0-6721b63a06f4/).

Discussion:

A feasibility study is the first step of any CCS project. Did yours include a capacity assessment? How much does that cost? How do you ask government for the money for it?
Because we know a lot about gas fields, e.g. via exploration studies and their production history, the initial feasibility study did not comprise too much, it costed probably less than $1M. In the Netherlands, onshore storage is not considered anymore because of public perception.

How do you monitor under salt?
Imaging sub-salt is always difficult. Also, the reservoir is already filled with gas. Which makes imaging CO_2 even more difficult. Wells pose the highest risk, so monitoring is focused on the integrity of wells. In case of irregularities shallow (3D HR) seismic surveys have been proposed (http://conference.co2geonet.com/media/1122/cato2-p18-4_vandeweijer-et-al_tno.pdf).

Ryozo Tanaka, RITE, How to reach an offshore injection phase, Japan case study

Ryozo announced that the Tomakomai project became operational on April 6, 2016. CO_2 is captured at a hydrogen production unit and will be injected at a rate of more than 100,000 t/yr for three years. Then, he explained a history of CCS development toward the CCS demonstration with an offshore storage site and prospect of CCS deployment in Japan.

They did a pilot project in Nagaoka that injected 10,000 tons of CO_2 between 2003 and 2005. They built one injection well and three observation wells into a saline aquifer within the footprint of a deeper gas field. The wells were 1 km deep and 4 km above the LNG reservoir. They monitored and observed both structural and solubility trapping of the CO_2. In 2005, they performed a survey of CO_2 storage potential in Japan. Their existing oil & gas fields and saline aquifers could theoretically store 100 years of emissions.

In 2008, the demonstration project planning was initiated by Japan CCS Company, which was jointly established by more than 30 Japanese energy-related companies. There was no industry contribution to funding. It has all come from the government in response to a G8 summit which prioritized CCS.

Construction on Tomakomai started 2012 and test operation was completed March 2016. They plan to inject for 3 years with monitoring for the purpose of demonstration through 2020. The source of the CO_2 is hydrogen production, using an amine process for capture. The CO_2 is injected into two aquifers. One is at 1100-1200 m depth. It is sandstone and the major repository. The second is volcanic rock at 2400-3000 m.

They have an ocean bottom cable with 72 sensors, geophones and hydrophones to monitor CO_2 plume. The Cable has another objective to collect seismicity data in real time, which is essential to ease major public concern on seismicity. They also do surveys of the seabed, seawater, sediments, and observation.

The regulations followed are in the existing Marine Pollution Prevention Act, which requires a permitting process. Guidance comes as well from the Ministry of Economy, Trade, and Industry (METI), which requires nine items to be looked into. There is an English version of the latter document.

They are currently performing an offshore CCS survey because the Japanese government wants to identify 3 or more storage sites with >100 Mt storage capacity. They expect wider CCS deployment R&D in 2020's and full-scale deployment in 2030's.

Discussion:

How do you pass cost on to private sector?
This has not been discussed yet. It will be part of a CO_2 emissions reduction policy.

What are the differences between site selection onshore and offshore?
The process is the same but the available data is different. It is easier to do a survey onshore. The costs are greater offshore. Site selection is easier where you have more data.

What was the outreach to public?
There is no national CCS outreach in Japan. In Tomokomai, the local government has been very supportive. They have led local lectures in universities.

Are you worried about the risk of earthquakes?
They are and that was part of the site selection study.

Do you have concerns about permanence given the seismicity?
People have concerns. But Japan CCS makes sure there are no active faults near the reservoir.

What gauges are required by regulations?
The main driver of Japanese monitoring is to protect the marine environment.

Owain Tucker, Shell, How to do risk management, including storage, monitoring, regulations and public acceptance, Shell case study

Shell has been injecting CO_2 at the Quest injection project. It is onshore but has injected over half a million tons of CO_2. Why doesn't it get much press? It's boring because it is all going to plan and nothing untoward is taking place. Shell has been involved with a number of large-scale CCS projects in addition: Boundary Dam (capture), Technology Centre Mongstad, Gorgon, and Peterhead.

Peterhead was going to be the first full-scale CCS project on gas power plant. It is a power plant in the northwest of Scotland. The plans called for a pipeline to shore from the Goldeneye Platform to reinject CO_2 offshore. The project was going to reuse a methane pipeline. They had 6 years of down hole, core, seabed, and seismic data.

The project was eventually cancelled because of a government policy reassessment. So there's a key lesson to be learned. We need to bring all stakeholders along with us, including government.

What are the requirements for offshore CCS? There are seven major considerations: capacity, temporal variability of CO_2 supply, permanence, monitoring, plan for unintended consequences, acceptability to society, and cost.

We also have to think about the ways to manage a CCS project. Can we just inject CO_2 or do we need to manage it by removing water or is there also the potential for EOR? The primary resource in CCS is pressure. Specifically, this resource is the pressure difference between the water gradient and the rock strength. At Goldeneye, they pulled out 47 Mt of gas. The space after everything settled out was 34 Mt. So you can be confident that you can store 20 Mt of CO_2. Depleted fields with aquifers are attractive storage sites for CCS.

We need to be aware of site selection when we do risk assessment. For example, Crystal CO_2 Geyser formed when a well was drilled into an aquifer containing CO_2, but there is no harm from it and it's now a tourist attraction. Because CO_2 is a natural thing, if it gets out on your platform, it is impossible for it to harm anyone onshore. Bow-tie risk analysis includes multiple barriers, threats as well as consequences.

The center of the bowtie is the loss of control of the hazard. You put in place preventative safeguards and corrective safeguards. This type of analysis works well to convince regulators of safety.

What's the biggest risk? Governments. Not leakage, not underperformance. At Peterhead, they did huge amounts of work with community to get public support, but the politics changed and the project was killed. Stakeholders can change priorities.

Discussion:

At the end of a feasibility study, how is the liability risk assessed?
It is provided by the storage operator until handed over to the government and then they take over responsibility.

Jun Kita, RITE - How to do environmental monitoring offshore, Japan case study

In Japan, the Act for the Prevention of Marine Pollution and Maritime Disasters was amended to encompass CO_2 storage in 2007. The operator of an offshore storage project must receive approval from the environmental minister, must implement an Environmental Impact Assessment (EIA), and must monitor the sea environment. The EIA must provide an estimation of CO_2 dispersion and impact assessment.

The process of developing an EIA requires simulation of leakage scenarios. For example, they looked a scenario in which there is leakage through faults that is undetectable by seismic survey. The output is CO_2 flux to seafloor. Another scenario looked at the CO_2 flux at the seafloor and modeled the concentration gradient of CO_2 in water column. Using these simulations, they have developed an understanding of the CO_2 impact on marine organisms and can estimate the impacted area.

They performed a baseline survey for Tomokomai that included sampling and measurements of seawater, sediment, seabed, and the biology. The megabenthos were studied by remotely operated vehicle. They are quite tolerant of CO_2, but important for fishermen.

In seawater, CO_2 increases carbonic acid, which dissociates into proton ions. So CO_2 decreases the pH, which leads to acidification. Therefore, they measured dissolved inorganic carbon (DIC), alkalinity, pH, salinity, and temperature.

In their studies, CO_2 decreased growth of *Sillago japonica*, a small baitfish. In flounder, CO_2 elevated the gut pCO_2 and decreased blood pH transiently. But the blood was buffered by plasma bicarbonate. This was a physiological compensation system for acidification over short exposure. Cocolithophores reduce calcification rates at low pH. Even a small decrease affects these phytoplankton. Calcifiers, like molluscs, echinoderms, and corals decrease calcification rates at concentrations of pCO_2 <200uatm. Fish, mollusks, and copepods suffer physiological disturbances as these levels as well.

The Quantifying and Monitoring Potential Ecosystem Impacts of Geological Carbon Storage project (QICS) was performed in collaboration with Plymouth Laboratory UK. It was the first controlled CO_2 release into seabed sediment. The biological impact was minimal and recovery was rapid. They concluded that CCS should not be seen as an impediment to ecosystems. More information can be found at www.qics.co.uk and in a special issue of International Journal of Greenhouse Gas Control.

The monitoring program required for offshore consists of monitoring for conformance of CO_2 behavior, demonstration of retention, and contingency plans. They are required to monitor CO_2 injection, wellbore condition, the reservoir, and the marine environment. There is a tiered approach to monitoring that includes routine, precautionary, and emergency procedures.

Discussion:

What does no impact mean?
Within natural variation

Is there a natural positive relationship with the marine environment? Is there a relationship with food security, a way to enhance biodiversity?
Marine ecology is very complicated. That's difficult to say. There is a lot of uncertainty.

How long did the permitting take?
It took three to four years including baseline study to get permit.

What was the recovery time of the QICS project?
CO_2 was released for 1 month. We saw small changes in microorganism diversity, but they recovered within 3 months. There was a greater impact from storms than CO_2.

In terms of the flounder blood chemistry, did they evolve to encounter this situation? Have they experienced it before?
Yes, they do have this ability to respond to transient changes in pH.

Paulo Seabra, Brazil - How to do EOR offshore, Brazil case study

The history of the Brazilian oil and gas industry shows great growth since the middle of 1970's when they began drilling offshore in shallow waters. In 2006 they discovered the pre-salt reservoir and the production increased quite well. Since then, they have been going deeper and deeper. Petrobras had the oil and gas monopoly until 1997, and then the industry opened to commercial entities. Now there are 40 companies, but Petrobras is still the main actor.

What is the Pre-Salt Reservoir? It is a huge carbonate reservoir of oil and natural gas with recoverable reserves of 8.3 billion barrels of oil equivalent. It is located 5,000-7,000 m below sea level in 2,000 m of water, under a layer of salt with approximately 2,000 m thickness in some areas. It is located around 300 km off coast and contains up to 20% CO_2. The Pre-Salt province is off the coast of Rio and São Paulo in the Santos Basin and Campos Basin. In 2006 the Lula oil field was discovered. In 2009, well tests were performed and in 2013, commercial production began.

In terms of their experience with CO_2 management for EOR, Petrobras has a lot of experience using CO_2 in Bahia state onshore, and R&D in CO_2 separation and corrosion control.

The main source of Brazil's contribution to the climate problem is deforestation. The motivation for CO_2-EOR is unusual. Petrobras and partners don't have target obligations for CO_2. But in order to get permits to extract oil in Pre-salt province, they are not allowed to vent CO_2 associated with the natural gas. Normally, when they inject CO_2 for EOR they do it at the end of the reservoir lifetime but they didn't do that in this case. Petrobras and partners are using the WAG (water-alternating-gas) injection process with CO2.

At the Lula field, there are currently four producers wells, which produce 100,000 barrels per day utilizing a FPSO (floating production, storage and offloading) unit, and inject 0.5 MM m^3/day CO_2 through one injector. They export 4.4 MM m3/day gas with 5% CO_2. This is the deepest offshore well with CO_2 injection in the world. They are currently separating CO_2 using spiral wound and hollow fiber membranes types. In many cases, they inject a mixture of CO_2 and natural gas with the aim to increase oil production. Up to 2015 over 1 million tonnes of CO_2 have been injected with four FPSO units in operation.

Initially, many people were against CO_2-EOR due to its costs, but now it is seen as an advantage because it allowed the increase the oil production without flaring the gas.

Discussion:

Have you considered shipping CO_2?
Yes, but it would be expensive. CCS was not of interest to Petrobras until now. We have no legal CCS framework established in Brazil. When we made the agreement to use the CO_2 instead of venting it in 2006, deforestation was the more important concern with regard to the climate..

What monitoring is undertaken?
We are using seismic monitoring and doing some R&D with 4D. Our main concern about leakage is with injection wells.

What are the considerations for selecting the reservoir and designing the flood in terms of geology?
Evaluation of all the possibilities – and this was the best one. [COMENT: I don`t remember this questions and I`m not sure if I understood my answer]

Pål Helge Nøkleby, Aker Solutions (presented by Philip Ringrose) – Subsea well stream processing, North Sea case study

There are significant available resources for EOR in North Sea and they know it improves oil recovery by 5-7%. But there are technical challenges: No CO_2 supply chain, no optimized wells, no space on platforms, pipelines not optimized etc.

Philip put the question - so how to change that? They can put together a subsea processing system from available building blocks. It is possible to buy most of the parts commercially, but Aker Solutions has also been developing a method to assemble purpose-designed susbsea facilities in 300m water depth. The system could also include a compact membrane packing in a unit that could be deployed to separate CO_2.

There are several ways to deploy the system. In the simplest, separation and reinjection of HC gas and CO_2 occurs subsea and oil and water are recovered topside. Technically, it is possible to do all the processing subsea and all that is recovered topside are oil and gas products. Such a system could potentially be ready in 5 years.

A subsea platform mitigates a number of the challenges of offshore CCS. Subsea installation avoids space limitations on platforms, weight limitations, mitigates issues with sudden release, and avoids downtime on platforms. A subsea system requires less power than gas injection. The Chromium steel required for subsea wells is probably sufficient to mitigate corrosion issues. The modules are retrievable and reusable.

Filip Neele, TNO (presented by Philip Ringrose) - Shipping Options for Norway and Scotland

Ship transport can provide flexibility during startup phase of CCS. In a recent study, TNO investigated the feasibility of offshore offloading of CO_2 carriers, either directly in a well, via a platform, or via a temporary buffer near the platform. The conclusion was that the CO_2 conditioning prior to injection (pressure, temperature, flow rate) is technically feasible for all three options. The same ship design (a capacity of the order of 30 kt) can serve most options: depleted fields, saline formations or oil fields.

As for the cost of CO_2 transport by ship, TNO determined that as CO_2 transport increases in distance, shipping becomes less expensive than pipeline. The break-even is about 500 km. The unit cost at a transport distance of 400 km is 14-21 euros/tonne CO_2. TNO study results are similar to results from ZEP (2011), perhaps a bit lower at longer distances.

Discussion:

What are the sweet spots for installation of this equipment?
In shallow water, you won't go for this. Need to go deeper than 100m probably.

What about extra emissions from shipping?
In Norway they have looked at gas powered ships. Diesel emissions are significant. You could have a green ship delivering CO_2 but it will be expensive.

What about risks during shipping, i.e. an accident?
CO_2 transport ships already exist. Transport of CO_2 used for food is happening so this is a matter of scaling it up. The question is who is willing to pay for all this?

Are there publications on shipping?
The report from the TNO study on shipping was published early 2016, contact Filip Neele for a copy of this study, and for information about other shipping studies.

Are the subsea units in use?
Yes, in at least two fields.

How long does a subsea system stay undersea without service?
I don't know, but I assume 25 years. It is also possible to pull up installations for servicing.

Tim Dixon, IEAGHG - How to meet international regulations covering offshore CCS -

The London Convention and Protocol is a global treaty to prevent ocean dumping of industrial wastes and it has worked. It prohibits dumping of all wastes unless listed in Annex 1. In 2006, CO_2 for sequestration was added to the Annex as follows: "the CO_2 stream must consist overwhelmingly of CO_2." The change came to force in 2007.

The change was agreed to by 87 countries but it moved quickly. Why? Because the oceans absorb about 1/3 of the CO_2 we've emitted, and that is changing the ocean chemistry and causing acidification. We are already beyond what the pH has been in the last 20 million years. The political target for the atmosphere is 450 ppm CO_2 but if we get to 500 ppm, the cocolithophores won't survive. They are major producers in the ocean, and their demise has the potential to significantly disrupt food chains. The London Protocol realized their role with CCS was a contribution they could make to preserve the health of the ocean.

In 2012, CO_2 specific guidelines for issuing a permit were developed, which include about 56 requirements that are generally qualitative rather than quantitative. The emphasis is on site selection and characterization. The end product is an impact hypothesis; a monitoring plan; and a mitigation and remediation plan.

The London Protocol has a transboundary export restriction that applies to CO_2 for storage, but does not apply for CO_2 EOR. They are working on fixing it for storage, but this is slow.

OSPAR is the Marine Convention for the Northeast Atlantic. It came into being in 1992 and prohibited some CCS configurations. Amendments for CO_2 storage were adopted in 2007 and came into force in 2011. It has a similar set of requirements for CCS.

Discussion:

According to the London Protocol, can the countries that have ratified CCS offshore do transboundary transfer?
Not yet, not until two thirds of countries have ratified the CCS export amendment.

End of day 1 wrap-up and discussion, led by Sue Hovorka and Tim Dixon

- One theme that emerged: there is some collaboration but there could be much more. CSLF is a nice vehicle – or perhaps boat – to move on collaboration.

- It's good to see SPE for stepping up to help to standardize views on capacity. This will act as valuable assurance to stakeholders. Such an effort could only be achieved through collaboration.

- The case study of the excellent Japanese work on marine biology and QICS that combines lab with field is powerful. It's an interesting model of collaboration. The projects were developed separately, but with a design that allowed them to be fused.

- International collaboration on ways to reduce shipping barriers would be valuable.

- There is great value in collaboration with industry. The downside is lack of transparency but the value is an unparalleled skill set, an example is seen in Goldeneye and the quality of Shell's work. We need to tap subsurface IP resources. How do we tap that?

- Many projects could be CO_2 stripped from gas streams, like Lula in Brazil. This is a global issue: there is often high CO_2 gas. But that also tells you where and what retention is. The basins are educating us.

- We saw a number of projects that wouldn't happen without collaboration such as Nagaoka and Peterhead.

- A second theme was novelty vs. routine and this is expressed in the analogy of the ducks. They are not identical but the similarity is sufficient to be educational. A very important question to consider is, why don't we know everything we need to know from Sleipner?

- We need to consider risk. Some believe offshore CCS is pretty ready for prime time, but there are still some things that need to be explored.

- Some of that is perception and some isn't. We need to deal with reality of risk. What do people outside CCS community understand?

- There are some real differences between offshore and onshore. More diversity has taken place onshore. The subsea installation from boats is really different.

- The more we study the more we learn and we get more assurance, especially with regard to the impacts on the environment and also with monitoring.

- There is a follow on to QICS called STEM CCS-M. It will look at the impacts of CO_2 release at the seafloor in deeper water more typical of the North Sea than QICS project which was shallow.

- From the experiences so far, there is a significant benefit from reusing offshore infrastructure

- We need to question our relationship with the public. The biggest worry from the public at Peterhead was the traffic. We need to show up to talk with locals.

- On a larger political stage, CCS is hard because setting up an operation takes several political cycles. When you talk to most people, they don't know what CCS is. They don't understand details like issues of intermittency v. base load. But it's a simple thing to say that a project like Quest is equivalent to removing 250,000 cars from the road.

- Good documents on offshore CCS can be found at CSIRO and USDOE.

- In terms of the financial sector, CCS is important to de-risk investments in potentially stranded assets with regard to climate change policies.

Country status and needs assessment reports and discussions

Sue Hovorka, Preliminary summary of survey responses

A survey had been sent out to assess status and needs relating to offshore CCS. There were 25 respondents from 17 countries.

The status shows variation among countries and opinions. There has been a lot of work on CO_2 source identification; less on more refined questions. In terms of information needed about transportation, risk and uncertainty are not irrelevant and cost is not irrelevant. There is a demand for pipeline and ship transport.

The status of knowledge on storage shows an investment in capacity assessments. There is debate on the need for EOR. The most needed information in order to progress is around storage capacity assessments.

The status of knowledge on integration suggests that source-sink matching and integration risk are relevant.

The status of policy and regulation shows that some countries have started developing policy to incentivize CCS, and that the policy to incentivize is viewed as important.

Most respondents agreed that additional information needed to progress toward CCS.

We had really good comments, vey reflective and captures diversity of thought. Some excerpts are included in the slides.

Discussion:

Risk seems prevalent through all these categories. It seems like something we need to explore further.

Figure 6. Susan Hovorka, BEG, spearheaded a pre-workshop survey to assess each countries' status and needs for offshore CO_2 storage.

Tony Surridge - South Africa

Why do we need CCS? Most of our energy is coal based. A full 90% is fossil fuels. CCS is a transition to a nuclear and renewable future. We have a mandate for CCS. It is one of 8 Near-term Priority Flagship Programs and the Cabinet has endorsed the CCS. Road Map. It is in the National Development Plan for 2030. The South African Centre for CCS is tasked with the technological development of CCS in South Africa.

There is a South African CCS Road Map. The first step is to evaluate the potential, which was completed and the results were favorable. The Storage Atlas was launched in 2010, and a pilot project is now underway with the goal of storing 10,000's of tonnes per year by 2017.

The South African sources of CO_2 are near coal fields in the central industrial area. The Atlas shows major offshore storage in 3 basins and in un-minable coal seams onshore. CCS in those seams sterilizes the coal. Most of the storage, 98%, is offshore and theoretically calculated at 150 gigatonnes capacity. 4 gigatonnes is required to store 4 million tonnes per year for 100 years. Hence there is sufficient motivation to continue.

The pilot CCS project aims to demonstrate safe and secure CO_2 storage in South African rocks. It will increase our technological capacity and raise awareness off CCS as well as provide the government with a means for further developing the regulatory framework.

The current focus is on Zululand basin on NE and near Mozambique. They are working on stakeholder engagement at a variety of levels, local and national including the National House of Traditional Leaders. If the Zululand site is unavailable, the alternates are Karoo, Algoa, or three offshore sites.

Our current regulations are sufficient for this exploratory phase. An economic study showed that transport is not relatively expensive, between 7-10% of the total calculated cost. A prospective carbon tax is insufficient to pay for CCS, so additional incentives are needed.

Discussion:

Are you looking at methane release from your coalfields?
We do not capture coal-bed methane in South Africa. It's more interesting to look at shale gas.

What's your renewables plan? Is it combined with CCS?
We have a vibrant renewables plan that includes wind and solar. We have a large coal-based electricity so easy to put variable supply into that grid. We know it works; it's integrating into the grid that we need experience. We haven't looked at CCS as a hybridization option but are planning to.

Do you have offshore gas reserves?
There is some down in the southeastern side, but not much. There's infrastructure and they are depleting, so it's a possibility.

Can you transport CO_2 to the Mozambique fields?
The pipeline from Mozambique will carry methane for a long time as methane is being found in Mozambique. It's difficult to dump your rubbish in someone else's backyard.

Zhou Di - China

In China, 90% of our energy is coal-based. They predict that in 2030, 2/3 will still be from coal. That's 24% of the global energy. Clean use of coal is 8th of 100 projects in the five-year plan of China. New coal-based power plants are halted because the government wants clean coal and renewables.

The sources of CO_2 are in the northeast and inland in north China. There are few sinks in the southeastern part where industry is, so offshore is the major focus. The major CCS projects are in the northeast and they are mostly for EOR.

In 2012, they did an assessment of CO_2 storage at the basin-level. The result is an Atlas. They estimated 1,655 GT of storage; 656 GT in just ten near-shore basins.

They are considering a storage demonstration project in Guangdong. The project has many industrial partners. The project is located in the Pearl River Mouth Basin, which has oil and gas production. It is the second most productive relative to Bohai Basin. The advantages are light oil and good porosity and permeability

For the demonstration project, the sources are from a refinery and a coal-based plant. The plant has 8 units. The third and fourth will be built CCS ready. They screened three fields for injection and are now focusing on one called ZH21-1.

They have a number of knowledge gaps. These include understanding offshore EOR techniques, transportation of CO_2, incentive policies, and regulations for liability and risk.

Discussion:

Who is paying for it?
The government provides financial support, but the company needs to pay half.

Is public acceptance an issue?
Most sites are in oil fields so there is not much of a program to bring about public acceptance. In the offshore, I don't think it will be a problem.

How do you get away from coal?
The government set a goal of 20% renewable by 2030; so the government is emphasizing clean coal. But that clean use refers to the plant, not CCS. CCS is a backup.

Is your main goal to convince the oil company to do EOR?
We want to convince them of storage, but we need oil company buy in and we need an incentive. CO_2-EOR has been accepted by the oil company before. The situation in China is not like the U.S. We really need oil. We need a real study.

Traci Rodosta - USA

As we venture into offshore, we have a lot of knowledge in oil and gas production, but not in storage. There are a lot of CO_2 sources within 10 miles of the shore in the Gulf of Mexico and in the Northeast. The onshore storage potential in the Northeast is limited, so we have to go offshore for CCS. Federal offshore waters are more than 2.3 miles from the coast or more than 10 miles in Texas. EOR is interesting in the Gulf of Mexico.

The Department of the Interior and the Bureau of Ocean and Energy Management are in the process of developing regulations for the outer continental shelf, but currently there are none in place.

They have performed initial and ad hoc assessments looking at economic modeling. They have kicked off assessments for storage potential offshore along East Coast and the Gulf of Mexico. They are looking at saline reservoirs and EOR. They have MOUs with other countries including Norway and Japan to help move up learning curve more quickly.

NETL has a lot of experience in the offshore. They funded a 2014 study showing that there is EOR potential in offshore. While knowledge and infrastructure exists; we face some challenges. How do we install CO_2 recycling facilities? Can we can reuse pipeline fairways or retrofit facilities for corrosion? How do we leverage understanding of optimum well placement? Can we use existing reservoir characterization to reduce uncertainty? How do we determine adequate and affordable CO_2 supply? Can we use subsea technology?

Future research includes risk management, cost associated with storage and EOR; collaborative Big Data GOM analysis; resource assessments; MVA technologies that include accounting for stored CO_2. They are looking forward to large-scale and commercial-scale injection projects.

Discussion:

How do you jump from assessment to large-scale project? Are you considering pilots?
We will follow same structure we have in regional partnerships.

What is next gen technology?
It's looking at technologies for CO_2 enhanced oil recovery. I'll get the ARI study for you. http://www.adv-res.com/pdf/CO2%20Utilization%20from%20_Next%20Generation_%20CO2%20Enhanced%20Oil%20Recovery%20Technology.pdf)

As for large-scale projects, what is the timing?
We want to have projects ready for 2025 time frame

Do you have plans for follow up outside the Gulf of Mexico?
Both East Coast and Gulf of Mexico are of interest in theory.

Sang Hoon Lee - Korea

Four ministries are included in CCS research and development in Korea: the Ministry of Science, the Ministry of Trade, the Ministry of Oceans and Fisheries, and the Ministry of the Environment. This complicated structure has both advantages and disadvantages.

In Korea, they have complicated geological structures on land, which are not optimal for large-scale storage. In addition, there is poor public acceptance of large-scale projects onshore. The major coal plants are in the west and southern parts of the peninsula. One will be selected for a 0.1 Mt capture plant and onshore storage. Most of the funding will come from the government.

The Ministry of the Oceans and Fisheries has been planning an offshore demonstration storage project. The project will store 1 Mt/year CO_2, which will be captured from a coal power plant. The Korea National Oil Company has been doing an assessment using oil and gas data. One depleted gas field and one saline formation are priority sites for the project, which is expected to last for 20-30 years. The monitoring strategy is nearly set up. Risk assessment is ongoing.

Public acceptance is not good for building a CO_2 pipeline so they are considering a hybrid transportation system that consists of shipping from the source to a platform and a pipeline from the offshore to the onshore. They are doing a transportation assessment to evaluate ship and pipeline design.

Korea has experienced an increase in CO_2 emissions because of our growing economy. They are now the 7^{th} greatest CO_2 emitter in world. The Korean government submitted an emission plan to the IPCCC that included CCS.

This year and next are very important for CCS in Korea. There has been a draft of regulations since 2015. The Korean government will decide whether to pursue CCS by 2017. Reduction of emissions is important to Koreans and there is greater acceptance of offshore projects than onshore projects. They need collaboration.

Discussion:

What made the 2017 the date for a CCS decision?
Because many ministries are involved, we need to have a plan.

Is the onshore pilot brine storage?
Yes

Do you do EOR?
No, because we have no oil fields onshore and only a few offshore.

Which ministry will fund the pilot?
The Ministry of Science

Joseph Essandoh-Yeddu - Ghana

In Ghana, they are not talking about CCS yet. They are more concerned with health, infrastructure and energy. They have sources of CO_2 from oil, electricity, cement, aluminum, iron and steel production. These used to be all hydropower, but now they use oil and gas as well. Grid access in Ghana is barely 80%. The share of the primary energy consumption of Africa, with a population of over a billion people is only 3%.

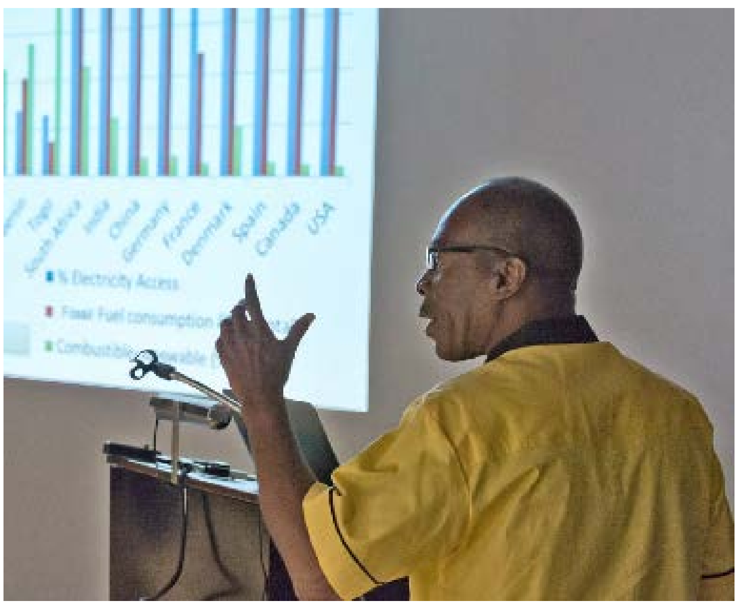


Figure 7. Joseph Essandoh-Yeddu of Ghana speaks frankly about the current potential for CCS is his country.

Ghana has not done an assessment of storage potential, of storage sites, of risk, of engineering readiness or monitoring strategies. In the movement of continents, Ghana used to be right next to Brazil's oil and gas fields, so they are looking for oil offshore in deep basins. They have gas and are using a floating production storage and offloading vessel such as Brazil uses.

Ghana is not ready for CCS. There is very little public knowledge of CCS. They currently have small emissions, but they have signed an INDC which intends to reduce GHG emissions by 45%v by 2030 with international support, which supports capacity building. “If you don't want the emissions from a 2000 MW coal plant, come help us.”

Discussion:

The people not on grid, what are they using?
Solar lamps. There has been a switch from kerosene and it has been a very dramatic change.

Why do you need donor money?
To meet our INDC

Is there CO_2 in offshore gas?
Very low amounts

Felicia Chinwe Mogo - Nigeria

Felicia gave this talk as a regulator and a researcher. She is a member of GESAMP, the London Protocol, and UNEP-GPA.

Nigeria has 853 km of coastline. The EEZ covers 315,950 nautical km^2. They have crude oil resources, vast rivers, huge shipping lines, and enormous seaports such as the Lagos seaport.

There are lots of regulations and regulatory agencies that would oversee CCS such as the National Policy on the Environment, the Merchant Shipping Act; the Federal Ministry of the Environment, and the Department of Petroleum Resources, among others. Nigeria is a signatory to the London Convention.

Figure 8. Felicia Chinwe Mogo discusses Nigeria's plans for CO_2 emissions reductions.

A motivation for CCS is that they have adopted a gas flare down policy to reduce GHGs. Nigeria is said to be the second largest emitter of CO_2 in Sub-Saharan Africa, emitting about 80.5 million tonnes of CO_2 annually.

The goal is to abolish the flaring by 2020. There has been an enhancement of drilling recently. Their crude is so light it is almost gas. The oil companies are building pipelines in the south of the country.

They have a goal of reducing emissions by 25%. CCS is part of that. They plan a new task force. CCS is expected to employ 100,000 people and reduce the health impact from flaring. Local communities are involved in developing structures for CCS.

Nigeria has a number of needs. There is a need for a CCS database of information. They need a procedure for doing an environmental risk analysis for CCS. There is a knowledge gap across all levels – from regulators to operators. There is also a lack of awareness and a need for coordinated effort in implementation and monitoring.

Going forward, global drivers of CCS will include a need for collaboration. The UN GESAMP secretariat, the IMO, London Protocol secretariat, and the International Sea Bed Authority could all be useful for this purpose.

It would be important to have a step-down program of what we have learned here in this workshop that includes national training, a survey of offshore CCS sites, and an analysis of the health of the ocean from a CCS point of view.

Discussion:

How much of your emission is connected to flaring?
Our emission doesn't really count in the global scheme, but we know it's a lot. We could use CCS to store the gas rather than undergo a flare-down.

Thanks for mentioning job sector. CTCN requires that funding add to economic growth of country.

Jazmin Mota - Mexico

Mexico has developed a map of potential storage zones. The west zone is excluded for tectonic reasons. The saline aquifers are estimated to have 100 GT of storage potential in 111 sectors, this estimation is being detailed through the regional assessments of each of the 9 sedimentary basins in the country. Now, they have started looking at Burgos basin.

In collaboration with PEMEX and CFE, the Mexican government has performed an assessment that includes all the large sources of CO_2 and the potential sinks, for deep saline aquifers or CO_2-EOR fields. One of the criteria is that CO_2 transport mustn't be more than 100 km from source to storage site. They have created a source map with oil and gas emitters and sinks.

In terms of EOR, Mexico has a long history of the technology since 1951. They have injected different fluids in different fields, including some examples of CO_2 injection. They are looking at a number of potential fields. The main field for a pilot project is Cinco Presidentes asset in the Brillante oil field. They have been working in collaboration with a number of agencies for this pilot project.

They have developed a strategy which includes short-, medium-, and long-term projects. Even when all the feasible projects for onshore CO_2 storage are considered, the offshore potential is huge. EOR may play a role onshore. The major challenge is CO_2 supply, as well as transport and cost. It may be easier to use nitrogen for EOR offshore. They have also been looking at CO_2 capture on methane hydrates.

Discussion:

You have huge experience in handling nitrogen. Can we learn about compression from PEMEX?
Yes, this is the same group that is working on CCS. The expertise is great and we can add it to the international expertise.

Charles Jenkins, Australia

Australia has a large number of offshore basins. They are located the northwest where Gorgon is located, off Barrow Island off Western Australia, and in the Southeast.

In the Southeast of continent, there is a lot of gas near CO_2 sources. This is where there is lignite, which is a dirty emitter. There are three power stations very close together and close to a sedimentary basin with a lot of oil and gas production. They see this as low hanging fruit for sequestration.

CarbonNet is a commercial-scale infrastructure network for CCS. It is a joint federal and state project that seeks to balance risk allocation and maximize investment. CarbonNet is investigating the potential for a 1 to 5 Mt/yr storage project from onshore lignite power stations. The basin capacity is 20 Gt overall and a detailed appraisal is underway. This has a real potential to make a difference in Australia's emissions. More information on the project can be found on the GCCSI's website. (https://www.globalccsinstitute.com/projects/carbonnet-project and https://www.globalccsinstitute.com/publications/carbonnet-storage-site-selection-and-certification-challenges-and-successes)

The project has both positive support and challenges. They do have regulations in place, but they are untested. They will soon be sequestering carbon at Gorgon, but this is on an island so actually an onshore project. There are plenty of sources and sinks, and they are well understood because of oil and gas activities. This is the most extensive oil and gas sector in Australia with a long history of onshore exploration and production. They have enough R&D to get started.

The major issues are the four "P"s. The first is pipelines. The first entity to do a project has to pay for them. This is a national infrastructure issue. The second is permitting. They will probably have to work with offshore legislation and federal legislation and there may be overlap of jurisdictions. People are the third issue. Public opposition is likely from fisheries, national parks, and people concerned with recreation. The last is politics. Currently there are no incentives for CCS to proceed. They have had a carbon tax in the past, but now it is abolished.

The missing piece is innovative financial engineering to make CCS investible. There are a lot of models out there and they should be sought out.

Discussion:

Is sequestration in the offshore and onshore different financially?
No, although it's more expensive offshore.

Isn't the missing piece the value proposition of CCS?
Yes. One Sleipner covers the emissions of 200,000 cars. Why doesn't the message get across?

Is there EOR?
There's not much to be gained from EOR here.

Do you have storage on the eastern shelf?
No. We have the Great Barrier Reef, so any sort of storage there is not going to fly. There is onshore storage in Queensland.

Weren't there some offshore leases advertised a few years ago?
Yes. Some are now taken up. The latest acreage has been taken.

What's the chance that the politics might change?
It's a bit unreadable at the moment. There is a climate change authority that's supposed to keep the government honest about emissions. The Prime Minister has asked them to study emissions trading schemes. This could be a sign of hope.

Is there storage in the northwestern basins?
We don't know.

Do you have a near-term plan for carbon reduction?
We have a plan called direct action, which amounts to giving money for not doing things that emit carbon. It is in essence a giant subsidy.

Simplicio Caluyong (presented by Tim Dixon) - SE Asia and CCOP CCS-M Initiative

CCOP CCS-M is a regional Initiative whose goal is to help countries to understand the potential for large-scaled CO_2 storage. The member countries include Indonesia, Malaysia, and China through their oil companies; Cambodia, Japan, Korea, Myanmar, Philippines, Thailand, Papua New Guinea, Thailand, and Vietnam through their national geological surveys. Taiwan is an observer organization.

The group maintains a running a program of meetings with the goals of forming a consensus on methodology, establishing and developing capacity; developing a CO_2 storage atlas, facilitating mapping, and furthering collaboration.

The initiative was established in 2013 when training courses were taught through the Global CCS Institute. In 2014, a case study on capacity was performed with the Norwegian Ministry of Foreign Affairs. The goal is to develop an Atlas by 2017 that integrates storage maps.

The Initiative has published a document, CCOP Guideline on the Methodologies for Selecting Geological Carbon Dioxide Storage and Estimation of Storage Capacities. This details capacity for CCS in the member countries.

They are also involved in alignment to international standards and practices and the also participate in the UNFC expert group on CO_2 storage classification. Their website is http://ccop.or.th/ccsm

Discussion:

Are you aware that there is a CO_2 injection onshore in Indonesia?
I think it's part of this program. [The 2014 case study focused on the South Sumatra basin in Indonesia.]

How are they funded?
Much of the funding is in-kind, for example giving staff time to work on the initiative. There is also some funding from GCCSI and Norway

Do they have inventory of sources?
Not in this project but in another report from ADB this is available at http://www.adb.org/sites/default/files/publication/31122/carbon-capture-storage-southeast-asia.pdf .

Do they have an EOR component or just saline?
Both. There was a proposed EOR offshore project for Indonesia. There was one proposed in Vietnam and Malaysia as well.

A line of action could be that regions are encouraged to work together using existing structures – in a similar way that GESAMP is working with Annex 6. They could be ambassadors of that region.

Nicholas Nordback (presented by Tim Dixon) – CGS Baltic Project

This is a new project that builds on a previous project, BASTOR 2. Latvia, Sweden, Lithuania, Russia, Poland are the most active members. The largest emitters in the region are Germany and Poland.

Finland and Estonia do not have onshore storage and so need to look offshore. Germany and Poland have large onshore reservoirs. The prospective storage sites are Middle Cambrian reservoirs in Latvia, Lithuania, Sweden, Poland and Russia. It is possible that there is limited injectivity.

There is a plan for a pilot project. The aims are to map potential storage sites, perform characterization, develop predictive modeling, do a pilot field study, and develop recommendations that could be useful for transnational CCS projects.

The project is just in initial phases, but hoping to ramp up to commercial scale by 2030.

Discussion:

Is Russia involved?
There was discussion of CO_2 pipeline through Baltic.

What is the status of Germany?
They are not formally part of this project.

There is not much experience in storage in this region?
Yes.

Guided Activity.
Led by Sue Hovorka and Philip Ringrose

Six important themes necessary to advance offshore CCS were developed with input from attendees. Attendees were asked to write down needs and actions that would result in progress within each of the theme areas. Working groups assembled around each of the themes to prioritize the recommended actions. A leader from each group reported back to the assembled workshop.

The six themes were:

- Technology and knowledge transfer
- Funding and finance
- Public engagement
- Pilot to full-scale offshore
- Regulatory development
- Infrastructure

Figure 9. Boxes are labelled with discussion themes for breakout sessions.

Technology and knowledge transfer recommendations:

1. There is a definite need and desire to go on a "deep dive" through technology of offshore, perhaps via a workshop. Such a workshop could include permitting, site integrity, cap rock integrity, environmental risk, etc.
2. To set up an offshore network that has an international base. There are already groups that could provide structure for such a network such as the IEAGHG. Such an international offshore network might be the daughter of this workshop. The major purpose would be to facilitate data sharing.
3. We need to develop of common standards around language, for example with storage capacity.

Funding and finance recommendations:

There is early engagement of different financing groups and different types of finance mechanisms. It was recommended to hold a workshop to review financial tools, especially for early stages of storage assessment for developing countries. The point is to get on the path toward a CCS project. A developing country may not have the funding for the whole project, but the goal is to at least get started. Examples of such funding groups are the World Bank, etc.

Figure 10. Breakout group discusses funding and finance recommendations.

Regulatory development recommendations:

Each country works differently so each approach needs to be tailored

1. It was recommended to do an analysis to determine factors of project success and failure. Do we have the right incentives in place?

2. After such an analysis, it was recommended to provide all that information in a global regulatory forum to generate a regulatory roadmap. The product would be a report that included a template structure with guiding principles that countries could use depending on their individual needs. It was pointed out that the IEA has developed such a regulatory framework for CCS, and holds annual meetings of its CCS Regulatory Network.
3. Lots of excellent information on CCS has already been developed. We need to let people know where to find it.

Public engagement recommendations:

1. We need to engage the diverse sets of stakeholders to make them understand why this is a winning proposal as opposed to not fitting with their goals. Among the public, there are two primary groups of stakeholders, roughly categorized as environmentalists and pro-industry. Dialog has to be tailored to these two constituencies but we need to convince both of them that CCS is in their interest. When speaking to pro-industry groups, the messaging is that CCS is a technology that will still allow them to have their lifestyle, while lowering our emissions. When speaking to the environmentalists the message is that CCS is a powerful transition technology that reduces emissions as we move to alternatives.
2. When developing public outreach: Ask don't tell. Use positive terminology and avoid making people afraid. Frame the messaging as focusing on wins from CCS.
3. Framing the industry of CCS in a different way from the oil industry could help with public acceptance.

Pilot to full-scale recommendations:

1. In order to generate pilot projects and to move to full-scale, a form of international collaboration is suggested to reduce costs. This could be started by forming a task force. CSLF could act as a model for the task force. One job would be to explore creative ways of finding funding, perhaps modeled on the International Ocean Discovery Program (IODP) drilling program, or CERN. An acronym was suggested: ACCT – Accelerating CCS Technology
2. It was also suggested bringing in the oceanographic and marine biological communities early on (as has been done in the UK).
3. It was recommended to hold a resource assessment workshop or special session at a meeting that tackles the question, what do you need? A topic of this workshop would include EOR and timing ability to stack storage with EOR. Another key would be to assess where EOR does work. Such an assessment would include regulatory guidelines and resources.

Infrastructure recommendations:

For infrastructure needs it was recommended to undertake an analysis assessment by workshop or taskforce. This could look at a set of scenarios such as onshore capture-offshore transport and injection, and other permutations; various means of transport; new build versus repurposing; EOR for new versus depleted fields. The goal of such a workshop would be to define next steps.

1. An infrastructure test program was recommended. Such a program could find late-life oil fields for CO_2 pilot studies and create a prioritized list of infrastructure requirements for such fields. It would do a pre-investment study on pipelines and wells that can be converted to be suitable for CO_2 uses. An aspect would be a pilot project that could be used for technology development. The assessment would also include a master plan for CCS roll out.

2. It was also recommended to undertake an assessment the source side, for example with regard to intermittency and composition.

Figure 11. Breakout group discusses infrastructure recommendations.

Follow up question from activity facilitators: How do you see these networks and task forces that have been proposed working?

3. They could be stand-alone networks and task forces.
4. They could become adopted by an existing body such as IEAGHG or CSLF. They could then be attached to already existing events such as DOE workshops.
5. It would be prudent to involve bankers and industrial participants as well.

Recommendations and next steps
Led by Sue Hovorka, Tip Meckel, Katherine Romanak, and Tim Dixon

Major Recommendations from the Workshop

The attendees agreed the following as the main or priority recommendations and activities from the workshop.

Workshop-type activities:
- Workshop – A more technical "deep dive" into aspects of offshore storage, which could include site management, permitting, monitoring, environmental monitoring.
- Workshop or task force on infrastructure – to undertake assessments, eg new vs re-use, technology developments, shipping vs pipelines
- Workshop/training on storage resource assessment
- Workshop on funding tools/sources for early stages of CCS resource assessment in Developing Countries

Project-type activities:
- International collaboration and funding mechanism for a demonstration project (like IODP)
- Develop infrastructure test programme/pilot project

Other activities:
- Study on project success/failure as a means of assessing offshore regulatory frameworks
- Resource page/web-site with links to key information sources
- Develop common language on storage
- Create an ongoing Offshore Network (IEAGHG?)

Katherine Romanak - CTCN and Attendee Recognition

The Climate Technology Centre & Network, CTCN, could hold some of the answers for stimulating collaboration on offshore storage. It is a mechanism within the UNFCCC Technology Mechanism with a mission of stimulating technology cooperation and the development and transfer of technologies to developing countries at their request.

The core sectors are mitigation, which includes reducing GHG emissions and adaptation, which includes strengthening climate resilience. A country can ask for support to identify technology needs, select pilot solutions, reinforce policy legal and regulatory framework, or increase access to funding. CCS is a recognized mitigation technology under the UNFCCC.

Figure 12. Katherine Romanak, BEG and Tim Dixon, IEAGHG, recognize Joseph Essandoh-Yeddu and Felicia Chinwe Mogo for being the first recipients of CTCN support for CCS activities.

The funding from CTCN is up to $250,000 per project. CTCN has been operational since 2015 with 70 requests for funding as of April 2016. They are looking to increase Network Members. Already the BEG and IEAGHG are members .

It appears that the first people funded through CTCN for CCS are Joseph Essandoh-Yeddu and Felicia Chinwe Mogo. “You are pioneers, blazing a trail for more CCS activities to be supported by CTCN in the future”, said Katherine Romanak.

Felicia Mogo responded: “We express our sincere gratitude. I have learned a lot about what’s possible. I see a lot of opportunities offshore. When I go back home I’m going to organize a workshop. We will take the message home at least to West Africa and take advantage of these opportunities. A foundation for the relationship is built. “

Lars Ingolf Eide, Research Council of Norway - CSLF Joint Task Force on Offshore CO_2-EOR

The purpose of the Task Force is to summarize current assessments on the status of global offshore CO_2-EOR. This includes identifying existing projects, technical barriers, and potential opportunities for collaboration; and presenting our findings to the CSLF ministers. It will focus on how the offshore is different than onshore.

Three reports already exist. In 2014 CSLF produced a report on technical barriers and R&D opportunities. And in 2013, CSLF produced a report on technical challenges. We are working on a report that expands these two reports and includes EOR. It was initiated in Riyadh in November 2015. The overall plan for the report will be presented in June 2016. We will present the final report in October 2017. The status of the report is that the draft is outlined. There are 5 countries involved and 8 writers.

Meeting End

The last day was a half-day Expo, which included a tour of University of Texas' capture demonstration facility, a poster session of US and others' work, and demonstration of monitoring and characterization tools such as the P-cable. It also included a session to introduce the work of the CTCN to developing countries and the process for submitting an application for CTCN support for CCS technology development.

The PowerPoints of the talks and posters are posted on the GCCC website at http://www.beg.utexas.edu/gccc/goi.php. It is intended that there will be a post-workshop survey.

Thanks to the steering committee and everyone involved for organizing the meeting. Tony Surridge had the final word.

Offshore CO_2 Storage

by **A.D. Surridge**

20 April, 2016

Should go where one must,
It's offshore or bust,
To store all the carbon away…

From atmosphere where,
Can lead to despair,
For climate change must not downplay.

Abundant pore space,
Can CO_2 place,
In storage that's perfectly safe…

Beneath the sea floor,
There's room for much more,
One should not assume it a waif.

No neighbours annoy,
The real McCoy,
Solution for storage today…

Been shown to succeed,
Achievement indeed,
Award to yourself a bouquet.

Appendix 1 - Break out group suggestions

TECHNOLOGY AND KNOWLEDGE TRANSFER

- Really need workshops/funding/programs to promote subsea infrastructure improvements (e.g. stacked membranes and more).

- Outreach committee of IEAGHG
- CFLF
- CTNF
- Development of international community.

- Follow successful international program models (non-profit) such as scientific drilling program to bring together selected group from different countries and experience levels to work on specific projects.

- Mobilize CTCN to fund tech transfer and match needs with experts.

- Develop collaborations between countries.
- --data sharing
- --funding streams

- Need a workshop (or workshop series) in Africa.

- Build a network (and its website) on offshore CO_2 storage to help knowledge sharing and collaborations.

- Data sharing
- --what data can be shared
- --when data should be shared? (Real-time data is needed?)
- --raw data should be shared?

- Well testing
- --what not to do

- Tech transfer – workshop on capacity assessments/methodologies.

- Workshop / task force on leakage mitigation.

- High level cost indications for different parts of the storage chain.

- How to take advantage from the offshore experiences regarding the utilization of different fluids for EOR.

- List the necessary research for offshore environmental impacts.

- Idea: existing projects could make their permit applications and supporting material "publically" available as a model for new projects to follow. Basic idea is to share what works and what pitfalls to avoid through detailed case studies.

- Methodology and case examples for economic evaluation on offshore CO_2 -EOR.

- Use an analysis of permitting under existing regulatory frameworks in various countries as a basis for designing perfect regulatory frameworks in developing countries.

- Develop a common methodology for storage resource classification.
- Collaboration project.
- Development of guidelines and draft regulations.
- Standardized language for assessments that indicates uncertainty.
- Battery underground storage system using CO_2. Or other innovative idea using CO_2.
- Educational incentives for training students in CCS geology, engineers, lawyers, PR folks.
- Need an offshore pilot open for training workforce and stakeholders (may not be practical to go to North Sea).
- Capacity building.
- Encourage industry, academics, and government collaboration. Funnel through appropriate national agencies to share data and knowledge.
- Hold CO_2 storage workshops in different regions.

<u>INFRASTRUCTURE</u>

- Overview of options based on regional and national geophysical situations.
- Can we build things (pipelines, wells) such that they can be converted to CO_2 later (pre-invest).
- Need an offshore pilot (open to many) that can be used for technology development.
- Create overview on when infra comes available, use this to model a "masterplan" for CCS rollout.
- Find late-life oilfields for CO_2 pilots.
- Economic analysis of offshore storage
  - --define scenarios
  - --new build vs. repurposing
  - --ship vs. pipeline
  - -- CO_2 capture onshore, transport, and injection offshore
  - --Goal: Identify key areas for technology development
- How to re-use existing infrastructure? What changes are needed? What does not need to change?
- Analysis of pre-existing infrastructure to be used on storage operations offshore. Analysis of different transport alternatives for CO_2 offshore.
- Is it more cost effective to retrofit existing equipment or use new equipment?
  - --e.g., EOR- CO_2 is it best suited to new oil recovery fields or nearly depleted fields?
- What is the best method of transporting CO_2 offshore?
  - --should pipelines be refitted or new pipelines built, or shipped?
- Understanding sources.

- Workshop/task force on HUBs, including ship transport/ship design.
- Get with an oil company!
- EOR tax and/or royalty relief in who OCS to stimulate this activity and begin infrastructure build out.
- Capacity building.
- Make all funding agencies aware.

PILOT TO FULL-SCALE OFFSHORE

- Get friendly with some marine biologists and oceanographers to help with your risk assessments.
- Manual that guides operators and regulators as to how to take onshore knowledge and experience and practices to the offshore.
- International injection project? If we do, what would be specification of the project?
- Why large scale? What is goal of large scale? Demonstrate, monitor, cost. Summarize high level learnings from prior projects, small and large.
- Pressure rules! Assess/map/identify offshore formations/areas at appropriate depths, settings that are under-pressured. Regional assessment of offshore areas.
- How do I start to look for potential storage?
- What level of information is needed to prove a storage site?
- Diverse stakeholders. Workshops/development of guidelines on capacity identification and site characterization.
- Most is temporary, related to construction. Actual operation will require few people.
- Awareness creation, bench marking, and development of action plan.
- Do a pilot onshore to test geologic feasibility—then move to offshore to develop infrastructure, etc.
- Timing issue—early on significant recycling, but sets up for later storage.
- How do I convert a platform for CO_2-EOR?
- Incentives for "first movers."
- Project insurance?
- Provide concrete policy and funding scheme to help incentive of full scale.
- Is there a way for a country to skip the standard development timeline (atlas, pilot, demo project, commercial project) and rapidly get to large scale injection? Idea is to avoid every new country to avoid reinventing the wheel.
- Modularization options for offshore.

- Analysis of technology improvement options.
o --e.g., review of application of advanced manufacturing techniques to offshore
o --modularization
o --SCO_2 power cycles

FUNDING AND FINANCE

- Develop international fund to finance any post-closure emergency responses to leakage and remediation. Use same of different fund to reimburse credits or allowances lost to leakage.

- Early appraisal.

- Engage of the global financial organizing into developing stages of CCS in developing countries.

- International co-financing and knowledge sharing for larger-scale demonstration of offshore storage.

- Workshop on very practical review of financial tools—how they will change as more case histories become available. How to hasten this process.

- Finance. What is economic upside of having a robust and mature CCS industry?
    - --"trickle down" effects

- For government, is this a revenue neutral concept or income stream?

- Funding: How to encourage government to fund non-profit CCS projects over other socio-economic projects.

- Have people invest in storage and pay them back their investment over time.

- [???] identify income opportunities of CCS projects.

- Tax incentives and CO_2 emissions, tax to emitters to fund CCS projects. Public private partnerships.

- Dedicated finance.

- Review of funding opportunities for small countries. (e.g. Ghana – how can the global CSC community all contribute ideas, short courses, technology bits to build a community demonstration project. A CCS "barn-raising").

- Mechanism for joint-funding (multination) an offshore pilot.

- International funding scheme.

- Link up to CTCN whose goals include mobilizing finance and could also include green climate fund, etc.

- Pilot/demo funded by govt. Commercial—funded by industry and costs passed to consumer.

PUBLIC ENGAGEMENT

- Two primary stakeholders. Pro-green, pro-industry. Dialogue may need some tailoring, but generally needs to convince both. Combine CCS w/renewables.
o --ask what needs/wants are—don't tell
o --positive terminology—avoid making PP afraid
o --frame message around "wins" for both groups

- --pro-industry—keep your car/use electric
- --pro-green—will make CO2 atm; this is a transitional tech.
- --does CCS need to be an NGO?

- Initial action items
  - --engage green NGOs?
  - --engage industry?

- Clearly demonstrate lack of risk in captured CO_2 storage relative to risk of increasing CO_2 atm. levels through infographics, outreach campaigns. Make public demand the solution.

- CO_2 storage risk management for general public in simple way (small courses, web courses, etc.).

- Education public more on CCS.

- Pamphlet that contextualizes offshore CO_2 storage risks (for public).
  - --addresses worst case scenario – CO_2 Macondo
  - --probability of CO_2 blowout
  - --amount of CO_2 release – environmental impacts

- Define value proposition for offshore storage.

- Current policy of releasing CO_2 into atmosphere is essentially dumping CO_2 into oceans and causing climate change.
- Must have clear studies of worst cases and what the consequences would be.

- Form team to focus on language of storage. We have risk, leakage, containment seal, pressure—it sounds scary already. Rule of sales "a confused mind always says no."

- We need to get the public want CCS. Why is solar and wind relatively wanted and CCS not?

- What poses a higher risk to future society—injecting CO_2 underground or releasing to atmosphere?

- Advertising campaign explaining the importance of CCS.

- Engage with "unfriendly" NGOs to explain factually the effectiveness of storage and the technical risks.

- Communicate the integration of monitoring, operations, and risk.

- Understand central stakeholder concerns and sensitivities.

- Providing strategy with help by social scientist.

- Create a systematic guidance or protocol, to promote government and decision maker's strategic compromise as well as general public acceptance.

- Must be compelling and show how CCS relates to people's daily lives.

- Do CCS projects with renewables to improve public acceptance.

REGULATORY DEVELOPMENT

- Only purpose of CCS is to mitigate negative atmospheric emissions. Need universal binding regulations to control CO_2 emissions.

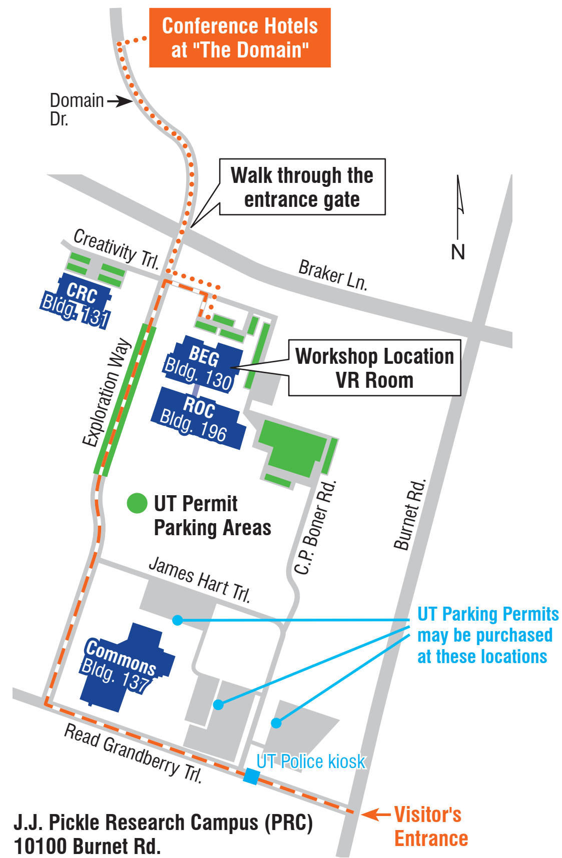
- Lobby Congress for carbon tax.
- Use 1st phase of carbon price to fund projects. Subsequent price increase through time.
- Must have some kind of policy to incentive CCS.
- What kind of advantages can we find on offshore storage vs. onshore to incentivize it.
- Need to establish a price for CO_2 emissions ASAP, e.g. no tax, no Sleipner if we need 6000 of them we need to price CO_2.
- Develop a synergy between environmental and accounting regulations.
- Find a potential person or party champion in DC to focus on regulatory issues.
- Get all the relevant ministries together to define roles, goals, responsibilities. Get on the same page to move forward with regulation development.
- Awareness creation through meeting, workshops (tailor-made), media advocacy, and release of journals.
- Analyze regulatory frameworks under which projects have been permitted to determine how well provisions have worked and what should be changed.
- What are the most important items to address in offshore regulations?
- Unlocking drafted regulations (i.e. testing them).
- Network to share regulatory advances in this issue.
- Environmental impact assessment including criteria/threshold for assessment.
- Clear regulations on liability of CCS projects extending to monitoring years after well injections stop.
- We need to reduce the post injection site care.
- --understanding what monitoring techniques are needed to reduce post injection site care.
- Government bear more long-term liabilities risk for early demonstration projects.
- Security liability/risk.
- Develop bilateral/multilateral programs on education in all aspects of CCS.

Appendix 2 – Agenda, Steering Committee, and Attendees

International Workshop on Offshore Geologic CO_2 Storage

April 19–21, 2016

Gulf Coast Carbon Center
Bureau of Economic Geology
The University of Texas at Austin
Austin, Texas, USA



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GCCC GULF COAST CARBON CENTER

sanedi South African National Energy Development Institute

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carbon sequestration leadership forum

CTCN CLIMATE TECHNOLOGY CENTRE & NETWORK

International Workshop on Offshore Geologic CO_2 Storage

SCOPE AND GOALS

- Perform a global needs assessment for offshore geological CO_2 storage.
- Initiate a discussion about the various aspects of offshore transport and storage to build an international community of parties interested in offshore storage.
- Facilitate countries to identify their specific issues, challenges, opportunities, etc.
- Identify synergies, common gaps and goals, and define common action items.

PRE-WORKSHOP ACTIVITY

Survey. Pre-workshop status and needs assessment survey for each country.

DAY 1 TUESDAY, APRIL 19, 2016 – BUILDING 130, VR ROOM

Introduction

9:00am	Welcome to BEG - *Scott Tinker, Director BEG*
9:15am	Workshop welcome - *Sue Hovorka, Tony Surridge*
9:30am	Workshop goals, expectations and logistics – *Katherine Romanak, Tip Meckel, Tim Dixon*
9:45am	Overview of CSLF Report on Offshore CCS – *Mark Ackiewicz*

Current State of Knowledge - Workshop Talks by Experts

10:00am	How to find and assess your storage offshore – *Tip Meckel*
10:30am	How to assess options for offshore transport and storage and onshore capture, Norway as a case study – *Philip Ringrose*
11:00am	Break
11:30am	How to develop a pilot injection project offshore, history of K12B – *Vincent Vandeweijer*
12:00pm	How to reach an offshore injection phase, Japan case study – *Ryozo Tanaka*
12:30pm	How to do risk management, including storage, monitoring, regulations and public acceptance, Shell case study – *Owain Tucker*
1:15pm	Lunch
2:15pm	How to do environmental monitoring offshore, Japan case study – *Jun Kita*
2:45pm	How to do EOR offshore, Brazil case study – *Paulo Seabra*
3:15pm	Subsea well stream processing/ship transport options, North Sea case study – *Philip Ringrose and Vincent Vandeweijer (with input from Paal Helge Nøkleby, Aker Solutions, and Filip Neele, TNO)*
3:45pm	How to meet international regulations covering offshore CCS – *Tim Dixon*
4:15–4:30pm	Wrap-up and summary – *Sue Hovorka and Tim Dixon*

Conference Dinner - County Line on the Lake, 6:30pm shuttle pick-up at the Lone Star Court Hotel

DAY 2 WEDNESDAY, APRIL 20, 2016 – BUILDING 130, VR ROOM

Country Status and Needs Assessment Reports and Discussions

9:00am	Summary of survey responses – *Sue Hovorka*
9:15am	South Africa – *Tony Surridge*
9:30am	China – *Zhou Di*
9:45am	USA – *Traci Rodosta*
10:00am	Nigeria – *Felicia Mogo*
10:15am	Ghana – *Joseph Essandoh-Yeddu*
10:30am	Break
10:45am	Korea – *Sang Hoon Lee*
11:00am	Mexico – *Jazmin Mota*
11:15am	Australia – *Charles Jenkins*
11:30am	SE Asia and CCOP initiative – *Tim Dixon on behalf of Sim Caluyong, CCOP, Thailand*
11:45am	Baltic BASREC project – *Tim Dixon (on behalf of Nicklas Nordback, GTK, Finland)*
12:00-1:30pm	Lunch

Guided Discussion – Sue Hovorka and Philip Ringrose lead

1:30pm	Summary of needs, probing needs and uncertainties, look for commonalities, distill topics, including business models - breakout groups and reporting back.
3:30pm	Break

Recommendations and Next Steps – Sue Hovorka, Tip Meckel, Katherine Romanak, Tim Dixon

4:00pm	Define next actions and explore mechanisms for implementation – e.g., follow-on workshops to address these needs, need for task forces, guiding documents, or other potential participants
4:40pm	CTCN presentation and recognition of attendees – *Katherine Romanak*
4:50pm	Introduction of CSLF Task Force on Offshore CO_2-EOR – *Lars Ingolf Eide*
5:00pm	Conclusions and End – *Sue Hovorka, Tip Meckel, Katherine Romanak, Tim Dixon, Tony Surridge*

Dinner on your own

DAY 3 THURSDAY, APRIL 21, 2016 – BUILDING 131, CRC*

8:30–11:30am Expo – visit to capture pilot, core viewing, demonstrations, posters and CTCN application overview (developing countries only). Meet in CRC Building #131.*

Schedule	8:30-9:30am	9:30-10:30am	10:30-11:30am
BEG Bldg. 131 - CRC Exhibition Space	All Participants	Group A	-----
Rochelle CO_2 Capture / Power Plant Tour	-----	Group B	Group A
CTCN Activity - Library in Building #130	-----	-----	Group B

* CRC building (#131) is the Core Research facility immediately west of the main BEG building (#130, where we will be meeting on Tuesday and Wednesday). Posters, core, and other demonstrations will be set up in the CRC warehouse facility.

Dr. Rochelle of the UT Austin Department of Chemical Engineering has a mini-power plant with experimental CO2 capture equipment (http://rochelle.che.utexas.edu/). The facility is a 5-minute walk from the CRC (Bldg. 131).

DAY 3 CONTINUED »

DAY 3 (CONTINUED)

OFFSHORE DEMONSTRATIONS:

- Dallas Dunlap and Ramón Treviño, BEG, *P-Cable Ultra High Resolution 3-D (UHR3D) System selected components and operations video*
- Jiemin Lu, BEG, *Examination and Discussion of Two Whole Cores from Miocene age rocks – Texas and Louisiana offshore areas*

OFFSHORE POSTERS:

Authors	Institute / Project	Poster Title
Kerstan Wallace, David Carr	BEG / U.S. DOE Miocene Mega-Transect	*Use of 3-D Dynamic Modeling of CO_2 injection for Comparison to Regional Static Capacity Assessments of Miocene Sandstone Reservoirs in the Texas State Waters, Gulf of Mexico*
David Carr	BEG / U.S. DOE Miocene Mega-Transect	*Offshore CO_2 Sequestration Research Program: Capabilities & Selected Research Highlights*
Michael DeAngelo, Dallas Dunlap	BEG / U.S. DOE TXLA	*Evaluation of the seismic structural and stratigraphic framework of the Upper Texas Shelf and its potential for CCS*
Isis Fukai	Battelle / U.S. DOE - mid Atlantic	*Mid-Atlantic U.S. Offshore Carbon Storage Resource Assessment*
Ellen Gilliland	Va. Tech (SSEB) / U.S. DOE - mid Atlantic	*Southeast Offshore Storage Resource Assessment: Mid-Atlantic*
Khang Lao	GeoMechanics Technologies / U.S. DOE - GOM Ship Shoal	*Assessment of CO_2 Storage Resources in Depleted Oil and Gas Fields in the Ship Shoal Area, Gulf of Mexico*
Iulia Olariu	BEG / U.S. DOE TXLA	*Preliminary stratigraphy and depositional framework of Miocene in offshore Texas and Louisiana for CO_2-EOR resource assessment*
Jack Pashin, Jingyao Meng, Denise Hills, Guohai Jin, Marcella McIntyre-Redden	OSU (SSEB) / U.S. DOE - eastern GOM	*Geologic Framework and CO_2 Storage Potential of the Eastern Gulf of Mexico Continental Shelf*
Rebecca Smyth, David Carr	GCCC / SSEB, EPRI, SE U.S. power companies	*2006-2011 GCCC Offshore Reconnaissance-Level CO_2 Capacity Studies, SE U.S. Atlantic and GOM*
Ramon Trevino, Dallas Dunlap	GCCC / U.S. DOE - TXLA	*First Seismic Acquisition Survey Cruise Using Newly Acquired "P-Cable" system*
Changbing Yang	BEG / U.S. DOE Miocene Mega-Transect	*Regional Assessment of CO_2–Solubility Trapping Potential: A Case Study of the Coastal and Offshore Texas Miocene Interval*
Nick Hoffman	Carbon Net Project Australia	*3D mapping and correlation of intraformational seals within the Latrobe Group in the nearshore Gippsland Basin*
		MMV constraints for shallow-water nearshore storage sites

International Workshop on Offshore Geologic CO_2 Storage

STEERING COMMITTEE

Tim Dixon, IEAGHG (Chair)
Katherine Romanak, BEG (Co-Chair, Host)
Susan Hovorka, BEG (Host)
Tip Meckel, BEG (Host)
Anthony Surridge, SANEDI (Host)
Mark Ackiewicz, US DOE
Di Zhou, China Academy of Sciences
Filip Neele, TNO
Paulo Negrais Seabra, Independent Consultant (formerly Petrobras)
Ryozo Tanaka, RITE
Owain Tucker, Shell
Philip Ringrose, Statoil

ATTENDEES

Name	Company
Mark Ackiewicz	US Department of Energy
Melissa Batum	Bureau of Ocean Energy Management
Patricia Berry	Southern States Energy Board
Susan Carroll	Lawrence Livermore National Laboratory
Tim Dixon	IEAGHG
Eric Drueppel	ExxonMobil URC
Jennifer Edwards	Bureau of Economic Geology, UT-Austin
Lars Ingolf Eide	Research Council of Norway
Joseph Essandoh-Yeddu	Energy Commission, Ghana
Isis Fukai	Battelle
Ramon A. Gil-Egui	Bureau of Economic Geology, UT-Austin
Ellen Gilliland	VCCER at Virginia Tech
Neeraj Gupta	Battelle
Jade Haug	Bureau of Ocean Energy Management
Kenneth Hood	ExxonMobil Upstream Research Co
Susan Hovorka	Bureau of Economic Geology, UT-Austin
Stephanie Ingle	Fugro Marine Geoservices, Inc.
Charles Jenkins	CO2CRC & CSIRO
Noel Kamrajh	SANEDI
Jun Kita	Research Institute of Innovative Technology for the Earth
Prasanna Krishnamurthy	The University of Texas at Austin
Kang Lao	GeoMechanics Technologies
Sang Hoon Lee	Korea Institute of Ocean Science and Technology

ATTENDEES CONTINUED »

ATTENDEES (CONTINUED)

Name	Company
Pengchun Li	South China Sea Institute of Oceanology, Chinese Academy of Sciences
Xi Liang	UK-China (Guangdong) CCUS Centre
Xueyan Liu	University of Texas at Austin
Jiemin Lu	Bureau of Economic Geology, UT-Austin
Tip Meckel	Bureau of Economic Geology, UT-Austin
Felicia Chinwe Mogo	Nigerian Maritime Administration and safety Agency (NIMASA)
Jazim Mota	Ministry of Energy, Mexico
Paulo Negrais Seabra	Independent Consultant
Lucie N'Guessan	ExxonMobil Upstream Research Company
Jack Pashin	Oklahoma State University
Chris Rathbun	Shell
Donald Rehmer	Bureau of Ocean Energy Management
Philip Ringrose	Statoil ASA
Traci Rodosta	DOE/NETL
Katherine Romanak	Bureau of Economic Geology, UT-Austin
Mahmood Shakiba	Bureau of Economic Geology, UT-Austin
Rebecca Smyth	Bureau of Economic Geology, UT-Austin
Tristan Stanley	International Energy Agency
Tony Surridge	SANEDI
Ryozo Tanaka	RITE
Ramón Treviño	Bureau of Economic Geology, UT-Austin
Luca Trevisan	Bureau of Economic Geology, UT-Austin
Owain Tucker	Shell
Bob Van Voorhees	Carbon Sequestration Counsel
Vincent Vandeweijer	TNO
Joshua White	Lawrence Livermore National Laboratory
Changbing Yang	Bureau of Economic Geology, UT-Austin
Michael Young	Bureau of Economic Geology, UT-Austin
Youqin Zou	Bureau of Economic Geology, UT-Austin
Zhou Di	South China Sea Institute of Oceanology, Chinese Academy of Sciences