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Greenhouse News

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GHGT-13 Summary Brochure, by Becky Kemp, IEAGHG

IEAGHG are pleased to announce that the GHGT-13 Summary Brochure is now available. This brochure, produced by IEAGHG, gives a comprehensive summary of the 4 days of this exciting conference and presents reflections and outcomes, key learnings and discussion points.

The GHGT conferences focus on presenting the cutting edge research on one low carbon technology option, CCS and the 13th conference in the GHGT series was held in Lausanne, Switzerland in November 2016. The hosts for the event were the world renowned Swiss Research Institute the Ecole Polytechnique Fédérale de Lausanne (EPFL), supported by the Federal Government of Switzerland and its Swiss Federal Office of Energy (SFOE). The event was held at the newly constructed Swiss Tech Convention Centre. The convention centre is a showcase for 'Clean Tech' incorporating geothermal supporting pillars heating and cooling; photovoltaic panels to produce electricity and prevent the inside of the centre from overheating, all of which reduces the greenhouse gas footprint of the centre which fully aligns with the conference aims. You can download the summary here: www.ieaghg.org/publications/general-publications/777-ghgt-13-conference-summary

In this issue

Changing the guard at IJGGC, by John Gale, IEAGHG

After taking the lead in setting up the International Journal of Greenhouse Gas Control, and having spent 10 years as the Editor in Chief, John Gale of IEAGHG is standing down at the end of 2016. His role as EIC will be taken on by Sean McCoy, formerly of the IEA in Paris. John will continue as a member of the Editorial Board.

Elsevier Journal Manager, Katie Eve presents John with a vintage bottle of wine to mark his retirement after 10 years as EIC for IJGGC

John said: "After selling the idea to Elsevier some 12 years ago and getting the journal into print, the journal has published over 2010 peer reviewed papers on CCS. I am very proud that IJGGC has established itself as a core reference source of peer reviewed literature for use in the IPCC assessment reports."

"I would like to thank Henri van Dorssen at Elsevier who took the chance on the idea of a CCS focused journal. I would also like the thanks the Editors who shared my vision and came in and did all the leg-work from the start; Stefan Bachu, Olav Bolland, and Xiqui Xue. Of course I should not forget all the other staff at Elsevier who have helped guide me and all the other Editors I have worked with, thank you all."

Southern Company our New Sponsor Member, by John Gale, IEAGHG

The IEAGHG is pleased to announce that Southern Company has become a sponsor member of the programme. Southern Company's subsidiary Mississippi Power is the owner/operator of the Kemper County CCS Project, which is a coal-fired electrical generating station currently under commissioning in Kemper County, Mississippi. USA.

The Kemper County Energy Facility is a lignite-fired integrated gasification combined-cycle (IGCC) facility. The plant design incorporates the air-blown TRIG™ technology jointly developed by Southern Company, KBR, and DOE at the Power Systems Development Facility in Wilsonville, Alabama. Lignite reserves near the plant site owned by Mississippi Power Company, will supply the feedstock for the IGCC plant. The plant will have a peak net output capability of 582 MWe. The peak capacity will occur when using syngas in the combustion turbine coupled with natural gas firing in the heat recovery steam generator duct burners. During syngas-only operations, the plant will achieve a net generating capacity of 524 MWe. The facility will employ advanced emissions control equipment to produce marketable by-products of ammonia, sulphuric acid, and CO_2. Over 65 percent of the CO_2 will be captured, making the Kemper County Energy Facility's carbon emissions comparable to a natural gas-fired combined cycle power plant. The commercial operation date of the Kemper County IGCC plant is expected to be around the second half of 2017. The plant will have a gross output of 740MW and 582MWe net peak. The peak capacity will occur when using syngas in

the combustion turbine coupled with natural gas firing in the heat recovery steam generator duct burners.

The estimated 3 million metric tons of CO_2 per year captured from the Kemper County Energy Facility gasification process will be transported via pipeline to two off takers for use in enhanced oil recovery operations at depleted oil production fields in Mississippi.

Source: https://energy.gov/fe/southern-company-kemper-county-mississippi

Interest for Carbon Capture & Storage Gaining Momentum in South Africa by Tony Surridge, SANEDI

The deployment of Carbon Capture & Storage technology in South Africa is gaining momentum. At the request of the stakeholders, a Carbon Capture and Storage Technical Workshop was held in KwaZulu-Natal Province, the area of interest for the Pilot CO_2 Storage Project. The Workshop was organised by the South African National Energy Development Institute (SANEDI) in partnership with the South African Department of Energy.

Some of the delegates who participated at the workshop

The workshop was planned for fifty (50) participants, however due to the demands made by Stakeholders from various sectors more than 150 people participated at the workshop. The workshop included experts in geology, geophysics and government officials from the key departments of Economic Development, Tourism and Environmental Affairs, Water and Sanitation, Cooperative Governance and Traditional Affairs, Energy, City of uMhlathuze, UMhlabuyalingana Local, Ugu District and Umuziwabantu Local municipalities, Environmental NGOs, the Academia, international peers and the general public. The greater than expected participation indicated the wide and growing interest in CCS, especially among non-CCS specialists.

The presentations focussed mainly on the technical aspects of CCS technology. The workshop provided the delegates with a platform to discuss and raise issues related to the planned Pilot CO_2 Storage Project (PCSP). The topics covered included lessons learned and case studies from various CCS projects throughout the world, site characterisation techniques, geological mapping for CO_2 storage, permitting requirements and the regulatory frameworks.

SANEDI CEO, Mr Kevin Nassiep gave an outline the Institute's mandate and its offerings in the energy sector as well as the organisation's commitment towards the fulfilment of the country's CCS mandate. Mr Nassiep emphasised the importance of CCS as one of the measures to mitigate carbon dioxide emissions that leads to climate change. CCS has been designated as one of the eight Near-Term Priority Flagship Programmes in the South African National Climate Change Response Strategy White Paper released late 2011. The CCS Roadmap was endorsed by the South African Cabinet during May 2012.

Mr Zama Mathenjwa, the UMkhanyakude District Manager and Acting General Manager of the KwaZulu-Natal (KZN) Department of Economic Development, Tourism and Enviromental Affairs (EDTEA), Northern Region thanked SANEDI for bringing the workshop to the KZN province, being one of the potential sites envisaged for the PCSP as part of its outreach programme.

The Chairperson of the SANEDI Board, Dr Ingrid Tufvesson, expressed her gratitude to the delegates for their participation and further indicated that Carbon Capture

Representatives from UMhlabuyalingana Local Municipality. From Left - Cllr December Mathenjwa, Honourable Council Speaker Cllr Busi Tembe and Disaster and Risk Manager Mr. Sibusiso Thwala

and Storage has the potential to prevent tens of millions of tonnes of carbon dioxide being released into the atmosphere. Noting that South Africa will continue to use fossil fuels in the foreseeable future, CCS is seen as a transitionary technology until renewables and nuclear energies can play a larger part in the energy economy. The Pilot CO_2 Storage Project is an essential step for a prospective full scale integrated CCS demonstration that is scheduled, under the South African CCS Roadmap, to precede a commercial roll-out.

The World Bank Group's appointed Pilot CO_2 Storage Project (PCSP) Technical Advisory Task Team, led by Battelle Memorial Institute, conducted presentations that focused mainly on site characterisation methods, regulatory frameworks and permitting procedures for geological storage of CO_2, lessons learned and case studies from existing CCS projects and the global status of CCS technology deployment. The World Bank Group presented on its support for strengthening capacity and knowledge building to create opportunities for developing countries to explore CCS potential.

Among the delegates were representatives from the UMhlauyalinagan Local Municipality. The UMhlabuyalingana Local Municipality is one of the areas identified in the Atlas on Geological Storage of CO_2 in South Africa for potential geological storage of CO_2 in South Africa. The Atlas identified five possible CO_2 geological storage basins summarising storage potentials in South Africa. Only two areas are of interest for the PCSP, namely onshore areas of UMkhanyakude District Municipality and the Sarah Baartman District Municipality. The Pilot CO_2 Storage Project is configured to improve understanding of the geology in South Africa and provide easy access to information that will allow for comparative studies thus improving information sharing and lessons learned. Currently, SANEDI is in consultations with local stakeholders regarding the process of conducting non-invasive seismic surveys in the potential geological CO_2 storage sites.

Much of the discussion from the delegates centred around the risks associated with geological storage of CO_2, impact on underground water sources, regulations and project legacy to the communities that are likely to be affected by the project. The progression of CCS towards a Pilot CO_2 Storage Project (PCSP) necessitates that a concerted effort to increase national awareness of CCS must be prioritised. The issues/concerns and questions raised by the delegates are scheduled to be addressed during the forthcoming 5th Biennial CCS Conference that will be held over two days at a venue in the KwaZulu-Natal province later during 2017. Closing the workshop in Richards Bay, Mr Mathenjwa emphasised that the authorities are now becoming better informed and equipped to proceed with the work on environmental permitting and compliance matters relating to CCS deployment in South Africa.

On the third day, the workshop relocated to the National Core Library in Pretoria. There, SANEDI hosted a core logging workshop for the Zululand Basin in conjunction with Battelle and the South African Council for Geoscience (CGS) to provide the participants with the results of the previous analysis of the archived cores. This workshop was mainly tailored for University students who were given the opportunity to obtain hands-on experience of such analyses.

The enthusiasm of the participants at the workshop indicated the expanding interest by Stakeholders in CCS as a greenhouse gas mitigation technology and forbodes well for the success of the PCSP.

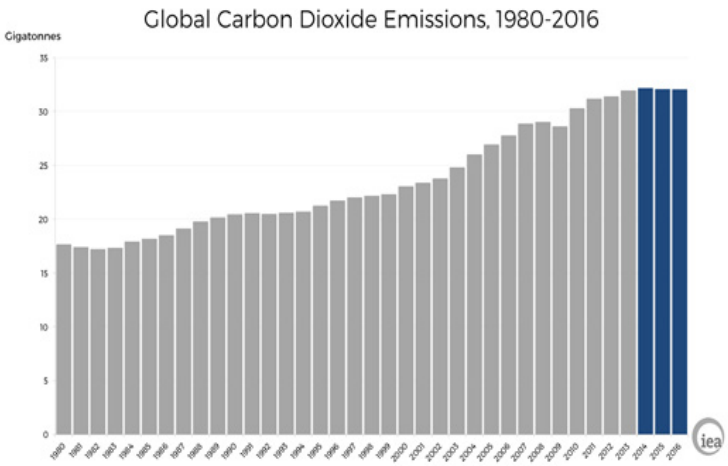
Mackenzie Scharenberg of Battelle supervising the participants at the Core Library, Pretoria

Press Release: IEA finds CO_2 emissions flat for third straight year even as global economy grew in 2016[1]

[1]www.iea.org/newsroom/news/2017/march/iea-finds-co2-emissions-flat-for-third-straight-year-even-as-global-economy-grew.html

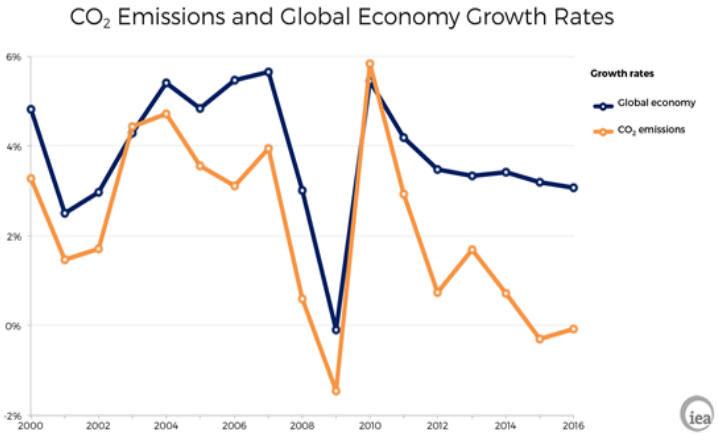
Global energy-related CO_2 emissions were flat for a third straight year in 2016 even as the global economy grew, according to the IEA, signalling a continuing decoupling of emissions and economic activity. This was the result of growing renewable power generation, switches from coal to natural gas, improvements in energy efficiency, as well as structural changes in the global economy.

Global emissions from the energy sector stood at 32.1 gigatonnes last year; the same as the previous two years, while the global economy grew 3.1%, according to estimates from the IEA. Carbon dioxide emissions declined in the United States and China, the world's two-largest energy users and emitters, and were stable in Europe, offsetting increases in most of the rest of the world.



The biggest drop came from the United States, where carbon dioxide emissions fell 3%, or 160 million tonnes, while the economy grew by 1.6%. The decline was driven by a surge in shale gas supplies and more attractive renewable power that displaced coal. Emissions in the United States last year were at their lowest level since 1992, a period during which the economy grew by 80%.

"These three years of flat emissions in a growing global economy signal an emerging trend and that is certainly a cause for optimism, even if it is too soon to say that global emissions have definitely peaked," said Dr Fatih Birol, the IEA's Executive Director. "They are also a sign that market dynamics and technological improvements matter. This is especially true in the United States, where abundant shale gas supplies have become a cheap power source.



In 2016, renewables supplied more than half the global electricity demand growth, with hydro accounting for half of that share. The overall increase in the world's nuclear net capacity last year was the highest since 1993, with new reactors coming online in China, the United States, South Korea, India, Russia and Pakistan. Coal demand fell worldwide but the drop was particularly sharp in the United States, where demand was down 11% in 2016. For the first time, electricity generation from natural gas was higher than from coal last year in the United States.

With the appropriate policies, and large amounts of shale reserves, natural gas production in the United States could keep growing strongly in the years to come. This could have three main consequences: it could boost domestic manufacturing, supply more competitive gas to Asia through to LNG exports, and provide alternative gas supplies to Europe. US and natural gas prospects will be explored in details in the next World Energy Outlook 2017.

In China, emissions fell by 1% last year, as coal demand declined while the economy expanded by 6.7%. There were several reasons for this trend: an increasing share of renewables, nuclear and natural gas in the power sector, but also a switch from coal to gas in the industrial and buildings sector that was driven in large part by government policies combatting air pollution.

Two-thirds of China's electricity demand growth, which was up 5.4%, was supplied by renewables — mostly hydro and wind – as well as nuclear. Five new nuclear reactors were connected to the grid in China, increasing its nuclear generation by 25%.

"In China, as well as in India, the growth in natural gas is significant, reflecting the impact of air-quality measures to fight pollution as well as energy diversification," said Dr Birol. "The share of gas in the global energy mix is close to a quarter today but in China it is 6% and in India just 5%, which shows they have a large potential to grow."

In the European Union, emissions were largely stable last year as gas demand rose about 8% and coal demand fell 10%. Renewables also played a significant, but smaller, role. The United Kingdom saw a significant coal-to-gas switching in the power sector, thanks to cheaper gas and a carbon price floor.

Market forces, technology cost reductions, and concerns about climate change and air pollution were the main forces behind this decoupling of emissions and economic growth. While the pause in emissions growth is positive news to improve air pollution, it is not enough to put the world on a path to keep global temperatures from rising above 2°C. In order to take full advantage of the potential of technology improvements and market forces, consistent, transparent and predictable policies are needed worldwide.

Press Release: Record interest in climate-related conference in Oslo

More than 250 of the world's leading researchers in carbon capture, transport and storage - better known as CCS - have gathered today at the Soria Moria Hotel and Conference Centre in Oslo.

"I am very proud to welcome so many leading CCS researchers to Soria Moria today. Without the technology they are developing, we won't meet our climate targets set in Paris," says Hans Jørgen Vinje, Head of the CLIMIT programme.

This year, CLIMIT will focus on its new programme plan and demonstrate how Norwegian and international research is helping to ensure that CCS can be used on a large scale and thus contribute to realising one of the most critical global climate initiatives. Norway is aiming to realise a full-scale CCS project by 2022, and is currently on track to be the first country to establish a full CCS value chain in Europe.

"This has been made possible by long-term research and development work supported by CLIMIT. When CLIMIT was established in 2005, the goal was to develop better, more sustainable technology for the capture, transport and storage of CO_2. The most mature technologies are now ready for use, but we still need to keep developing the technology to bring down the costs involved," says Vinje.

CLIMIT SUMMIT has become an important meeting place for professionals from the world over working on CCS. This year, CCS leaders from the American Department of Energy, the EU's Zero Emission Platform and the EU's ACT research programme have all chosen to come to Norway.

This year's programme will feature, amongst other things, presentations from CLIMIT's project portfolio, which includes the companies Aker Solutions, GE, InflowControl, NORSAR and SINTEF. Almost 260 participants are expected at this year's #SUMMIT2017, drawn from the worlds of research, industry and public bodies.

CCS is one of the three most important climate initiatives we know of, in addition to renewable energy and energy efficiency. According to International Energy Agency and the UN's Intergovernmental Panel on Climate Change, CCS is absolutely essential if the climate goals agreed in Paris are to be reached.

About CLIMIT:
CLIMIT is the national programme for research, development and demonstration of CO_2 management technology. The programme is a collaborative partnership between Gassnova and the Research Council of Norway.

The outlook for how CO_2 management will be implemented globally and nationally has changed since the CLIMIT programme was established 12 years ago. The focus of the programme has changed from the promotion of CO_2 capture solutions for gas-fired power plants towards capture solutions for other sources, such as industrial emissions. In 2016, the CLIMIT Secretariat developed a new programme plan that will focus research funding on the new reality. The programme plan was adopted in December 2016.

The programme plan designates three main focus areas going towards the year 2022:

- Early full-scale CO_2 value chains in Europe
- Large-scale storage of CO_2 on the Norwegian continental shelf in the North Sea
- Future solutions for CO_2 management

11th IEAGHG Monitoring Network Meeting, by Lydia Rycroft, IEAGHG

The 11th IEAGHG Monitoring Network Meeting will be held in Traverse City, Michigan, USA from June 13th – 15th, 2017. The theme of the meeting will be "The Cost and Value-effectiveness of Monitoring: what key drivers are required to deliver an optimum outcome?" The meeting brings together Carbon Capture and Storage experts from across the world and this year will have a sub-theme relating to leveraging oil and gas industry experience for CO_2 storage. The full agenda of the meeting can be found on the IEAGHG website.

CALL FOR POSTERS

We welcome poster submissions for this event on topics directly related to the monitoring of CO_2 storage. The deadline for submission is the **CLOSE OF BUSINESS Thursday 20th April**. Please send submissions directly to Lydia Rycroft at **lydia@ieaghg.org**.

This three day meeting will include a field trip to Battelle and Core Energy's EOR study area site. The Agenda for the meeting includes:

- The Application Of Oil & Gas Production Experience Including CO_2-EOR To Storage In DSFs
- Project Updates – Fresh Insights Into Recent Monitoring Data And Advances In Characterising The Overburden
- Offshore Monitoring Developments
- Monitoring - Modelling Loop: New Advances
- Innovation In Monitoring Techniques And Advances In The Understanding Of Rock-Physics
- Wellbore Integrity
- Near-Surface and Surface Baseline Monitoring –Site-Specific Subtleties And Leakage Monitoring
- Group Exercise
- Induced Seismicity And Microseismic Monitoring
- Monitoring – Selecting A Cost And Value-Effective Approach That Aids Policy And Outreach Objectives

For further details please consult the Monitoring Network site at the IEAGHG website: **www.ieaghg.org**.

New IEAGHG Technical Report: 2016-09 4th CCS Costs Network Workshop

The fourth meeting of the CCS Cost Workshop was held on March 23th - 24th, 2016 at the Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts. This function is now designated as the CCS Cost Network under the auspices of the IEA Greenhouse Gas R&D Programme.

The purpose of the workshop is to share and discuss the most currently available information on the costs of carbon capture and storage (CCS) in electric and other industrial applications, as well as the current outlook for future CCS costs and deployment. The workshop also seeks to identify key issues or topics related to CS costs that merit further discussion and study.

New IEAGHG Technical Report: 2016-10 Techno-Economic Evaluation of Retrofitting CCS in a Market Pulp Mill and an Integrated Pulp and Board Mill

Globally, the pulp and paper (P&P) industry is the fifth largest industrial source of CO_2 emissions. Recently, the Paris Agreement has highlighted the target of achieving below 1.5°C temperature rise. In order to achieve this goal, bio-CCS has an important role to play to achieve this target.

In a pulp mill, the CO_2 emissions arise mainly from its recovery boiler, multi-fuel boiler and lime kiln. The majority of this CO_2 originates from the combustion of biomass, which renders it as carbon neutral if the biomass used as raw materials of the pulp production is grown and harvested in a sustainable manner. If the CO_2 emission from pulp and paper industry is captured and permanently stored, then this could be considered as a potential carbon sink. As such, the pulp and paper industry could be regarded as an industry with potential for the early demonstration of both bio-CCS and industrial CCS.

This study provides an assessment of the performance and costs of retrofitting CCS in a Nordic Kraft Pulp Mill (Base Case 1A) and an Integrated Pulp and Board Mill (Base Case 1B). Different configurations of capturing CO_2 (90%) from the flue gases of the recovery boiler, multi-fuel boiler and lime kiln were examined.

Key Messages:

- This study has established the baseline information in evaluating the techno-economics of retrofitting post-combustion CO_2 capture plant using MEA as solvent to (a) an existing Kraft pulp mill producing 800,000 adt pulp annually and (b) an existing integrated pulp and board mill producing 740,000 adt pulp and 400,000 adt 3-ply folding boxboard annually.
- It should be highlighted that performance of retrofitting CCS in an existing industrial complex is very site specific. This is also true if CCS is deployed to an existing pulp mill.
- For the market pulp mill, the excess steam produced by the mill is sufficient to cover the additional demand from the CCS plant. For an integrated pulp and board mill, there is less excess steam available for the CCS plant, therefore the addition an auxiliary boiler is required.
- The retrofit of CCS increases the levelised cost of pulp (LCOP) produced by the market (standalone) pulp mill in the range of 20 to 154 €/adt (4 – 30%), and increases the LCOP produced by the integrated pulp and board mill in the range of 22 to 191 €/adt (4 – 37%). This translates to a CO_2 avoided cost (CAC) between 62 and 92 €/t CO_2 for the pulp mill and between 82 and 92 €/t CO_2 for the integrated pulp and board mill.
- This study assessed the sensitivity of the cost if incentives to the renewable electricity credit, CO_2 taxes, and negative emissions credit are provided. It can be concluded that the most favourable route to encourage the pulp industry to deploy bio-CCS is by providing sufficient incentives for their negative emissions.

New IEAGHG Technical Report: 2017-01 Case Studies of CO_2 Storage in Depleted Oil and Gas Fields

CO_2 storage has now been tested at a number of demonstration sites around the world, including some depleted oil and gas reservoirs. The use of depleted reservoirs can offer some advantages because the geological characteristics that are pertinent to CO_2 storage, such as the distribution of porosity and permeability, have been pre-determined. Although depleted hydrocarbon fields can show strong evidence of fluid retention, there are risks associated with existing wellbores and the possibility of caprock deterioration.

In 2016 IEAGHG published a study reviewing key factors that influence CO_2 storage in depleted oil and gas fields based on four detailed examples. Comparisons were made between storage operations in depleted fields (with or without enhanced hydrocarbon recovery) and storage in saline aquifers with the approaches required in modelling, monitoring, reporting, economics, and operational strategies. Four main case studies were chosen; The Goldeneye (UK North Sea), Cranfield (Texas, USA), SACROC (Texas, USA) and Otway (Australia).

Key Messages:

- The use of depleted reservoirs for CO_2 storage can offer advantages because the geological characteristics that are important to CO_2 storage have been pre-determined.
- There is strong evidence for secure containment if a rigorous risk assessment and characterisation has been conducted.
- Evidence from these case studies has shown that CO_2 storage does not have a detrimental impact on adjacent oil and gas fields.
- AZMI (Above Zone Monitoring Interval i.e. a formation above the reservoir and caprock) pressure monitoring has proved to be an effective tool for tracking CO_2 in heterogeneous and complex reservoirs (e.g. Cranfield). AZMI is an active area of research and development.
- Monitoring approaches should take into consideration the background geochemical reactions in aquifers that might be prone to ingress from brine or CO_2 above a storage reservoir. Simplistic approaches may not be effective and could lead to flawed inferences without an adequate understanding of natural variation in groundwater geochemistry.
- Risks associated with increasing pressure are predominantly and most commonly mitigated by keeping pressures below pre-production levels.
- Case study evidence suggests oil and CO_2 miscibility might improve storage estimates by up to 3% whereas residual gas and CO_2 miscibility could reduce capacity by up to 6%.
- At Goldeneye proprietary CO_2-resistant cements could be utilised if they can be shown as superior to 'normal' Portland cement but have not yet been thoroughly tested in terms of their compatibility.
- An in depth understanding of potential risks is essential to allow for balanced cost-benefit modifications and improved costs analysis.

New IEAGHG Technical Report: 2017-02 Techno-Economic Evaluation of Deploying CCS in Standalone (Merchant) SMR Based Hydrogen Plant using Natural Gas as Feedstock/Fuel

Hydrogen is a key raw material to other energy intensive industries. Globally, nearly 90% of the hydrogen produced industrially is consumed by the ammonia, methanol and oil refining industries. In the future, hydrogen could play an important role in the decarbonisation of space heating (i.e. industrial, commercial, building and residential heating) and transport fuel (i.e. use of fuel cell vehicles).

Currently, the steam methane reformer (SMR) is the leading technology for H_2 production from natural gas or light hydrocarbons. Modern SMR based hydrogen production facilities have achieved efficiencies that could reduce CO_2 emissions down to nearly 10% above its theoretical minimum. Further reduction of CO_2 emissions from hydrogen production would only be possible by the integration of CCS.

This study provides an up-to-date assessment of the performance and costs of a modern SMR based H_2 plant without and with CCS producing 100,000 Nm^3/h H_2 and operating as a merchant plant (i.e. standalone plant - without any integration to an industrial complex).

This study presents the economics of deploying CCS in an SMR based hydrogen

plant capturing CO_2 from the (a.) shifted syngas, (b.) PSA's tail gas or (c.) SMR's flue gas. Each capture option was evaluated using IEAHG's standard assessment criteria against a Base Case (i.e. H_2 plant without CCS).

Unlike other studies in the series, the capture of CO_2 from an SMR plant is a commercial operation. This is one of the main sources of industrial and food grade CO_2 in the market globally. However, only 3 sites around the world have demonstrated the integration of CO_2 capture with CO_2 transport and storage. These include (a.) Port Arthur Project in the USA, (b.) Quest Project in Canada, and (c.) Tomakomai Project in Japan.

Key Messages:

- The Base Case consists of: (a.) feedstock pre-treatment, (b.) pre-reformer, (c.) primary reformer, (d.) high temperature shift reactor and (e.) pressure swing absorption or PSA in single train arrangement producing 100,000 Nm^3/h of H_2 (purity >99.9%). It consumes about 14.21 MJ of NG and emits about 0.81 kg of CO_2 per Nm^3 H_2 produced. It has a surplus of ~9.9MWe electricity which is exported to the grid.
- The current industry standard for capturing CO_2 from an SMR Based H_2 plant is the capture of CO_2 from the shifted syngas using MDEA solvent. Four other CO_2 capture options were then evaluated as part of this study. These include: the use of H_2 rich burner in conjunction with capture of CO_2 from shifted syngas using MDEA; the capture of CO_2 from PSA's tail gas using MDEA, or the use of Cryogenic and Membrane Separation; and the capture of CO_2 from flue gas using MEA. These options involve the CO_2 capture rate in the range of 56% to 90%.
- For all the CCS cases, the addition of the CO_2 capture increases the total plant cost by 18% to 79% compared to the Base Case. This corresponds to an additional total capital requirement) of around €40 to €176 million (Q4 2014 estimates).
- For all bar one of the capture options considered, the incorporation of CO_2 capture increases the natural gas consumption by 0.46 to 1.41 MJ/Nm^3 H_2. Similarly, all options with CO_2 capture resulted in a reduction of the surplus electricity that could be exported to the grid. These changes resulted to an increase in the operating cost of hydrogen production by 18% to 33% compared to the Base Case.
- Adding CCS to an SMR based H_2 plant results to an increase in the Levelised Cost of Hydrogen between € 0.021 and € 0.051 per Nm^3 H_2 (from € 0.114 per Nm^3 for the Base Case). This corresponds to a CO_2 avoidance cost (CAC) of between €47 and €70 per tonne of CO_2.

New IEAGHG Technical Report: 2017-03 Techno-Economic Evaluation of HYCO Plant Integrated to Ammonia / Urea or Methanol Production with CCS

Ammonia/urea and methanol production are the pillars of the basic chemicals industry worldwide. Ammonia/urea is an important commodity used in the agriculture (fertiliser) and food industry. Whilst methanol is an important feedstock in production of various chemicals and fuel used in our daily lives. Globally (except for China), these commodities are mainly produced from NG or light hydrocarbons. It should also be noted that both urea and methanol production (combined) are the largest users of CO_2 second only to CO_2-EOR.

This study presents a detailed baseline information of the performance and cost of deploying CO_2 capture in a SMR Based HyCO plant using natural gas as feedstock / fuel and operating as a captive plant (i.e. integrated within an industrial complex) with an aim to evaluate the cost of capturing additional CO_2 from the SMR's flue gas.

Key Messages:

- An SMR could be integrated into an industrial complex such as an ammonia or methanol plant.
  - In general, the syngas generation used in ammonia plant is based on SMR in tandem with an air blown ATR. This is the typical conventional ammonia production configuration (i.e. no need of air separation unit).
    - Normally, with large methanol plants as presented in this study, the SMR is always in tandem with an oxygen blown ATR.
- The addition of capture of CO_2 from the flue gas of SMR increases the energy demand of the plant.
  - For the ammonia/urea production – an additional 8.6MWe of electricity is imported from the grid.
    - For the methanol production – an additional 17.9 MWe of electricity is imported from the grid.
- In general, the addition of CCS increases the levelised cost of production.
  - For the ammonia/urea production – this increases by 23 €/t urea.
    - For the methanol production – this

increases by 24 €/t methanol

- The CO_2 avoided cost of capturing additional CO_2 from the SMR plant is in the range of €80 to 100 per tonne CO_2 for both cases.
- It is well established that CO_2 is used as reactant to both urea and methanol production. This is considered as mature technology. This study should provide a good basis for understanding the performance and cost of implementing both industrial CCS and CCU.

New IEAGHG Technical Report: 2017-04 CO_2 Capture in Natural Gas Production by Adsorption Processes for CO_2 Storage, EOR and EGR

CO_2 capture from natural gas (NG) can be done by several technologies, e.g. solvent scrubbing, membranes, adsorption or cryogenic processes. The future demand in NG might trigger development of NG fields with high CO_2 partial pressure, for which pressure swing adsorption (PSA) processes could be more suitable than the other options. Besides, PSA processes have the potential to reduce energy consumption and costs. Hence, there is a requirement to evaluate the feasibility of PSA processes for CO_2 capture from NG at high pressures.

The aim of this work was to evaluate PSA processes for removal of CO_2 from NG at high pressure. For this, the study performed a techno-economic comparison of PSA with an amine based solvent process and identified candidate materials for the PSA process. Researchers from SINTEF Chemistry & Materials and SINTEF Energy Research have carried out this study for IEAGHG.

The key messages from the report are:

- An iterative pathway was applied to find a PSA cycle design with maximum CO_2 purity. The final design consists of a 12-column multi-feed cycle with around 85% CO_2 purity and is the first reported design for the separation of CO_2 and CH_4 at a pressure of 70 bar and flowrates of 500 000 Sm^3/h.
- The final PSA design has about 50% higher costs of CO_2 removal (including CO_2 conditioning, transport and storage) and NG sweetening than the reference amine process. However, the process is not yet optimised, so there is ample room for improvement.
- Data availability for suitable adsorbent materials is severely limited. This study used a carbon molecular sieve (CMS) and identified other materials worthwhile of further investigation, such as certain zeolites, titanosilicates, metal organic frameworks (MOFs), zeolitic imidazolate frameworks (ZIFs) and honeycomb monoliths.
- A combined approach of material and process optimisation could significantly reduce the cost of the proposed PSA design, potentially even below the cost for the reference case of amine scrubbing.
- Improving the feasibility of the PSA process for CO_2 capture from NG requires more work in several areas. This includes optimisation of the PSA cycle to minimise NG losses, investigation of novel cycle concepts (e.g. hybrid of single and dual PSA), evaluation of advanced adsorption materials and data for suitable adsorbents at high pressure. This is basic research and modelling work that should be taken up by related research groups from academia and industry.

New IEAGHG Technical Report: 2017-05 2017-05 Combined Meeting of the IEAGHG Monitoring and Modelling Networks

The combined meeting of the IEAGHG Monitoring and Modelling Networks took place at the Edinburgh Centre for Carbon Innovation from the 6th - 8th July 2016. The meeting brought together leading experts from research and industry to discuss the latest work and developments, with around 60 participants from 11 countries participating.

The theme for this meeting was 'using the modelling-monitoring loop to demonstrate storage performance more effectively'. Sessions on monitoring included induced seismicity, novel monitoring techniques, monitoring costs, near-surface natural variability, monitoring CO_2-EOR, wellbore integrity issues, modelling environmental conditions, updates from ongoing and closed projects, lessons from other industries, modelling reservoirs and overburden, pressure measurements and conformance in the monitoring modelling loop.

New IEAGHG Technical Review: 2017-TR1 Ethane and CO_2 shipping

The study is a first stage assessment of a novel concept of transporting ethane from the USA in dedicated maritime carriers to Europe, which are modified from standard designs to be equipped to carry both ethane and CO_2, so that CO_2 can be transported back (back hauled) to the USA for use in CO_2-EOR operations.

The key messages from the study are:

- In 2016, the USA began exporting ethane first by pipeline to Canada and then by liquefied carrier to Norway in March 2016 and the UK in September 2016. Ethane is used as a key feedstock for plastics production and other industrial uses.
- It may be technically feasible to convert existing designs of liquefied ethane carriers to be dual purpose and carry liquefied CO_2 as well.
- The driver for transporting CO_2 to the USA is the projected increase in the demand for CO_2 for EOR in the USA. The study concludes that the single largest constraint to CO_2-EOR growth in the USA is the lack of sufficient economically viable sources of CO_2 in the USA itself.
- Whilst ethane is being exported to Europe now the same ships are unlikely to be converted to carrier Liquefied CO_2 as well.
- New ships would need to be built to meet any market demand to back haul CO_2 to the USA.
- Whilst there is a potential near term demand for CO_2 for EOR in the USA (if oil process recover to $100/barrel), there is unlikely to be large quantities of transportable CO_2 from Europe in the foreseeable future
- LPG and ethane trades to the Far East from the US Gulf Coast are also now starting and there may be similar considerations on those routes for future investigations of this type.

New IEAGHG Technical Review: 2017-TR2 Review of CO_2 Storage Basalts

Key Messages

- Basalts are important storage sites to consider for CCS as they comprise approximately 10% of the Earth's surface and are often located in areas where no other storage options exist. Basalts have a high weight percentage of Ca, Mg and Fe rich minerals which react with CO_2 to form carbonates.
- Basalts are volcanic rocks that often form a series of layered deposits with a fine grained matrix and upper vesicular surfaces caused by degassing. The presence of vesicles increases the porosity and permeability of the rock and the reactive surfaces.
- Comparatively rapid mineral trapping created by reactive cations reduces the risk of leakage as the CO_2 becomes permanently trapped within the host reservoir rock's structure. The use of basalt would also increase the number of reservoirs available for storage as caprock integrity is only required for tens of years rather than thousands.
- Two high profile sites, CarbFix in Iceland and the Wallula project in Washington State have both injected and monitored CO_2 storage in basalts since 2012. Evidence from both sites shows that injected CO_2 reacts relatively rapidly to form carbonate minerals.
- Overall, the two pilot sites conducted to date have shown great promise for the successful use of basalts as CO_2 storage reservoirs. The potential for further storage globally is vast, especially in areas such as India, the USA and possibly South Africa. Further research is still required, predominantly focusing on the amount of water required, where it can be sourced from and at what expense.
- Some other igneous rocks with high magnesium contents (>12% by weight) are geochemically more reactive with CO_2 compared with mafic basalts. There is strong evidence that these ultramafic rocks cause natural carbonation reactions in regions of the world where they are exposed, for example, the Oman ophiolite. However, ultramafic rocks are not as widespread in comparison with basalts and often form coarse grained plutonic complexes which have more restricted reactive surfaces.
- The use of mine tailings derived from ultramafic host formations has been investigated in South Africa as a means of CO_2 sequestration. The process could have application in Finland, Canada, Australia and the USA.

New IEAGHG Technical Review: 2017-TR3 Reference data and Supporting Literature Reviews for SMR Based Hydrogen Production with CCS

The IEA Greenhouse Gas R&D Programme has recently published two reports (2017/02 and 2017/03) covering the topic of CCS in SMR based hydrogen manufacture. As background to these two published study the contractor (AmecFosterWheeler) undertook three technical reviews which provided both key reference data and supporting information for technology decisions made for the two main published studies. The 3 Technical Reviews are combined in this report as reference material for members and others reading the main reports.

The technical Reviews undertaken were:

1. A review of the Current State-of-the-Art Technologies for Hydrogen Production. The aim of the review was to highlight the key features of the different hydrogen production processes commercially deployed worldwide. In particular, the different process characteristics, plant performance, points of CO_2 emission and relative CO_2 concentration of the leading hydrogen production technologies are presented.
2. A review of Technologies for CO_2 Capture from Hydrogen Production Unit's This review provided a general overview of the state-of-the-art of technologies that are commercially available for capturing the CO_2, mainly in connection with hydrogen production.
3. A Review of Ongoing Major Demonstration Projects for CO_2 Capture from Hydrogen Production Unit's. This technical review provided an overview of the major on-going Demonstration CCS projects applied to SMR Hydrogen Plants with a focus on the CO_2 capture system. In particular, the technical approach used for the design and execution of the Demonstration plants and the relevant peculiarities are outlined. The following CCS demonstration projects were considered in the review: The Port Arthur Project (Air Products), The QUEST Project (Shell), The Tomakomai Project (JCCS ltd/METI), The Port Jerome Project (Air Liquide)

The information included in the review was collected from the public domain and integrated, where available, with comments received from the Companies involved in the relevant projects, with the aim of including the most recent public data available about each demo project at the time of publication of the review, September 2016.

4th Post Combustion Capture Conference, by Siân Twinning, IEAGHG

The call for abstracts for PCCC4 has now closed with 73 abstracts received. It has been interesting to see a shift in the submissions compared to PCCC3. Whereas, just two years ago, papers tended to be predominantly research–based, there are now a high percentage reporting very real results from pilot plants and demonstration projects, addressing challenging issues such as corrosion and solvent degradation.

The abstracts are currently in the review process with the programme due for release in early May. As well as the technical sessions, there will also be not-to-be-missed opportunities to tour the National Carbon Capture Centre at Wilsonville and the Kemper Energy Facility – although, as spaces will be limited, we recommend you register early to avoid disappointment (registration will open to coincide with the programme announcement).

Sessions will cover the key areas of post-combustion capture, including 2nd/3rd generation capture technologies, amine-based solvent development, biphasic solvents, environmental impacts, equipment corrosion issues, pilot & demonstration projects, process integration & economics, solvent degradation, capture process modelling, as well as industrial applications of CO_2 capture.

We look forward to seeing you in Birmingham, Alabama, in September.

EU Project to Advance Environmental Monitoring for Offshore CO_2 Storage Projects, by Tim Dixon, IEAGHG

STEMM-CCS (Strategies for Environmental Monitoring of Marine Carbon Capture and Storage) is an EU Horizon 2020 funded project that will develop and test environmental monitoring at a controlled release of CO_2 in the North Sea. The project has just held its first annual meeting in Kiel, Germany. The key objectives of the project are:

- To produce new tools and techniques for environmental monitoring as well as CO_2 emission monitoring, leakage detection and location, quantification and assessment
- To generate new knowledge of the reservoir overburden by direct investigation of natural geological and manmade features, specifically chimneys.
- To deliver the first CCS demonstration project level implementation of an ecological baseline, incorporating geochemical and biological variability
- To promote knowledge transfer to industrial and regulatory stakeholders

The project builds on the QICS project which was a shallow controlled release, and the ECO2 project which through offshore surveys tested monitoring and baseline measurements at offshore sites. STEMM-CCS will develop new tools and test these on a controlled-release in the sea-bed at a typical water depth in the North Sea, around 110m.

The project will start to collect environmental baseline data from summer 2017 with a permanent seabed lander. The project recognises the complex and variable nature of environmental baselines and will provide new detailed evidence on this. The controlled release test will be in the summer of 2019. Various new devices are being developed for the monitoring, include sediment samplers, AUV- and ROV- mounted chemical and acoustic sensors. The project aims not only to show that any emitted CO_2 can be detected but to attribute (identify the source) of the CO_2 with tracer-based and process-based (stoichiometric) techniques, and very importantly to test techniques to quantify the CO_2, an area in need of attention for carbon accounting purposes.

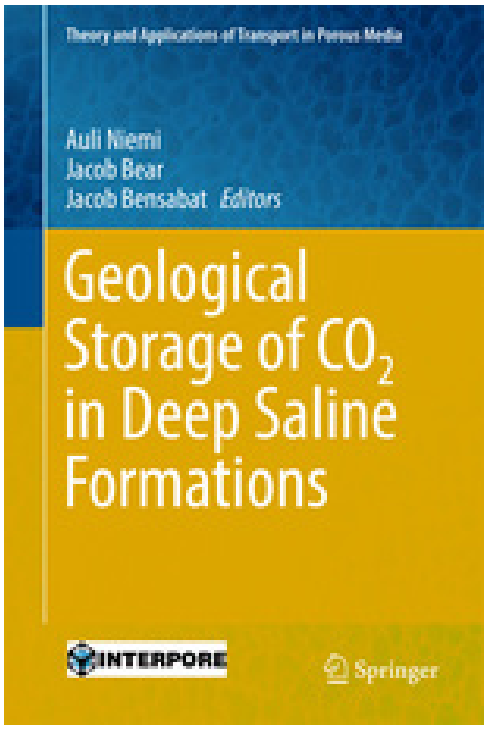
The project is coordinated by The UK's National Oceanography Centre, with a consortium of partners representing the leading marine science organisations in the EU and Norway. IEAGHG sits on the Stakeholder Advisory Board for the project to provide feedback.

The project has just held its first Annual Meeting in Kiel, hosted by GEOMAR. The quality of the research expertise and facilities being brought to this work are impressive. Good progress is being made especially on sensor development, and planning is well advanced on the development of the engineering and techniques to collect data and the planning of the research cruises using UK and German research ships. GEOMAR also hosted a visit to their marine research facilities to see up close some survey hardware which will be used on this project.

This is an exciting and unique project that will advance offshore environmental monitoring, specifically CO_2 leakage detection and quantification, and CO_2 storage site characterisation. More details will be shared and discussed at the forthcoming IEAGHG Monitoring Network meeting in June 2017 in Michigan.

For more information and updates see: www.stemm-ccs.eu/

Publication: Geological Storage of CO_2 in Deep Saline Formations



This book offers readers a comprehensive overview, and an in-depth understanding, of suitable methods for quantifying and characterizing saline aquifers for the geological storage of CO_2. It begins with a general overview of the methodology and the processes that take place when CO_2 is injected and stored in deep saline-water-containing formations. It subsequently presents mathematical and numerical models used for predicting the consequences of CO_2 injection.

This book provides descriptions of relevant experimental methods, from laboratory experiments to field scale site characterization and techniques for monitoring spreading of the injected CO_2 within the formation. Experiences from a number of important field injection projects are reviewed, as are those from CO_2 natural analog sites. Lastly, the book presents relevant risk management methods.

Geological storage of CO_2 is widely considered to be a key technology capable of substantially reducing the amount of CO_2 released into the atmosphere, thereby reducing the negative impacts of such releases on the global climate. Around the world, projects are already in full swing, while others are now being initiated and executed to demonstrate the technology.

Deep saline formations are the geological formations considered to hold the highest storage potential, due to their abundance worldwide. To date, however, these formations have been relatively poorly characterized, due to their low economic value. Accordingly, the processes involved in injecting and storing CO_2 in such formations still need to be better quantified and methods for characterizing, modeling and monitoring this type of CO_2 storage in such formations must be rapidly developed and refined.

IEAGHG are also pleased to announce that our General Manager, John Gale, has written the first chapter of this book, titled: 'CO_2 Storage in Deep Geological Formations: The Concept'.

You can purchase the book here: **www.springer.com/gb/book/9789402409949#aboutBook** ●

Conferences & Meetings

This is a list of the key meetings IEAGHG are holding or contributing to throughout 2017. Full details will be posted on the networks and meetings pages of our website at www.ieaghg.org.

If you have an event you would like to see listed here, please email the dates, information and details to: becky.kemp@ieaghg.org.

Please note that inclusion of events in this section is at the discretion of IEAGHG.

11th IEAGHG Monitoring Network Meeting
13th - 15th June 2017, Traverse City, Michigan, USA

IEAGHG Summer School
17th - 22nd July 2017, Regina, Canada

7th High Temperature Solid Looping Cycles Network (HTSLCN) Meeting
4th - 5th September 2017, Luleå, Sweden

4th Post Combustion Capture (PCCC4) Network Meeting
5th - 7th September 2017, Birmingham, Alabama, USA

IEAGHG CCS Costs Network Meeting (Invitation Only)
13th - 14th September 2017, London, UK

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Greenhouse News is the newsletter of the IEA Greenhouse Gas R&D Programme (IEAGHG). IEAGHG is funded by member contributions from IEA member countries as well as other developed and developing countries and industrial organisations that have an interest in implementing technical options for GHG mitigation. A list of this membership can be found on the website. Greenhouse News provides information on worldwide developments in the field of GHG abatement and mitigation. It is published four times a year and is free of charge. Mailing address changes and requests for copies of this newsletter should be sent to the address below. For further information about IEAGHG and suggestions for articles, please email or write to the :

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