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Results of the CO₂GeoNet Open Forum 2017 (ROF2017))

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Public

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1 Introduction

The CO₂GeoNet Association draws together key research institutes with CO₂ storage and utilisation research expertise. Association now comprises 28 institutes from 21 European countries.

Acting as a "virtual institute" with more than 300 researchers involved in studies on the geological storage of carbon dioxide, its activities encompass joint research, training, scientific advice, information and communication.

CO₂GeoNet plays a valuable and independent role in enabling the efficient and safe geological storage of CO₂, and the annual Open Forum conference it organises, now in its 12th year, has become a "must-attend" event for stakeholders, including EU representatives, industry, regulators, public authorities, NGOs, and the research community. The open forum gives a unique opportunity to meet and interact directly with Europe's largest group of researchers on CO₂ geological storage. All the presentations held in the 12th CO₂GeoNet Open Forum and following workshops are available at: <http://conference2017.co2geonet.com>.

The Open Forum is traditionally followed by a number of workshops, three of which, this year were dedicated to ENOS.

This document presents the open forum and the workshops, and summarizes on event visibility and key messages.

2 CO₂GeoNet Open Form 2017

2.1 Overall programme

As the targets of the Paris Agreement are translated into actions by countries worldwide, the need for large-scale deployment of CO₂ Capture and Storage will become even more apparent.

To emphasise the critical role that CO₂ storage is ready to play in climate change mitigation strategies, "Driving CCS towards implementation" was chosen as a theme for the 12th CO₂GeoNet Open Forum.

The two-day event has been followed, as in the last two editions, by two parallel targeted workshops: "Fit-for-purpose solutions for CCS" co-organised with IRIS and Gassnova, and "Bringing CCS into new regions - developing countries" co-organised with BGS and GEUS.

Moreover, all the Open Forum attendees had the opportunity to interact with the researchers involved in the ENOS project, during two additional ENOS workshops, "Experience sharing focus groups: framing the topics" and "Research priorities ad future pilots".

The final days were dedicated to internal ENOS workshops, where activities in different work packages were discussed.

During the Open Forum, some additional specific events have been organised by CO₂GeoNet to start a Young Researchers' Network: a poster session for the young researchers to present their scientific work in the CCS area at Icebreaker event and a session on the third day on carrier planning and networking.

The Open Forum has been endorsed this year by CSLF, ZEP, EERA, Assocarboni and the EU (through the funded Horizon2020 project ENOS).

2.2 Monday May 8 - The role of CCS in national mitigation strategies

During the morning session, after the welcome by the CO₂GeoNet Secretary General and a summary of the objectives of the Open Forum by the association President Ton Wildenborg, the invited key talk has been held by Niels Berghout, energy analyst at the IEA. In his presentation "After 20 years: can CCS reach its potential", he has summarized the progresses done by CCS in the last 20 years, and its increased role to keep the increment of temperature well below 2 C°. In the presentation conclusions, Berghout has pointed out that policy support is needed to reduce costs and uncertainty across the CCS chain, for moving from a single-project to an infrastructure approach, and for supporting the retrofit of existing infrastructures.

The rest of the session has been devoted to the international perspectives on the impact of the Conference of Parties (COP). The role of CCS in delivering the Paris agreement, with a focus on the major CCS demonstration projects in the US, has been discussed by considering the necessity of reconciling employment and climate actions.

The second session has been focussed on how to integrate CCS in the industrial sector, by considering also CO₂ usage and valorization. The initiatives supported by the European Commission have been illustrated, together with a detailed description of the Tomakomai CCS demonstration project in Japan.

The third and last session of the first day included a series of presentations regarding the use of captured CO₂ and the integration of CCS with various energy technologies.

Researchers from USA, Switzerland, Sweden and France have illustrated how CCS is an important component in the subsurface energy resource management, how it can be coupled with geothermal energy extraction, the deployment opportunities of BECCS and the prospects and recommendations for the CO₂ utilization in the industry.

2.3 Tuesday May 9 - Accelerating implementation of CCS

The second day was devoted to how lessons learned on CCS at a range of scales can be used to build up trust in the reliability of the CCS technology, support decision makers and accelerate CCS implementation.

The first session of the day, spanning throughout the whole morning, focused on the results and knowledge produced in the Quest project, the stage 3 of the Otway project, the research and development activities and major demonstration projects in Japan, the small scale field test of CO₂ storage in a saline aquifer and in a CO₂-EOR initiative at Wellington field in Southern Kansas.

Going to Europe, four projects have been presented: the Ketzin pilot site (for the post injection phases), Hontomin (from characterization to injection activity), the Sulcis Fault Lab (to define with a deliberate release of CO₂ the leakage-or-sealing characteristics of a near-surface fault) and the UK GeoEnergy test Bed (to study the potential CO₂ impact to a near-surface aquifer and the needed monitoring network). All of the sites presented except for Ketzin are ENOS test sites.

In the afternoon, the last session of the Open Forum highlighted how results from projects supported by the European Commission can contribute to accelerate the implementation of CCS.

Detailed presentations have been given for the following projects: Heletz (Israel), the Rotterdam Nucleus, a series of activities in Greece, IMPACTS, ECCSEL, ROAD, and Smeaheia (Norway).

In his closing remarks, Ton Wildenborg, President of CO₂GeoNet has warmly thanked the participants for their contributions during the discussions after each session, and anticipated that the major outcomes of the Open Forum will be included in a report, which will be brought to the attention of policy makers and high officers of funding agencies in Europe and in the European nations.

2.4 Parallel workshop 1 - Fit-for-purposes solutions for CCS

The break-out discussion started with a technological focus related to the presentations given at the workshop. However, it quickly turned into a discussion on barriers that should be overcome in order to deploy the technical solutions presented. It was quite clear that the barriers are not technological, but rather are lack of political support, lack of public incentives and lack of public awareness.

The presentations given at the workshop showed that the technology is available. Norway has plans for large scale storage in the Smeaheia field in the North Sea. This project could be realised due to political support in Norway and the needed financial capital will hopefully be granted from the government. Similar public support is lacking elsewhere in Europe.

Other presentations included BECCS and an innovative approach to combine CCS and geothermal energy. These are examples of technical solutions with a business

potential that could be realised if public support is available to demonstrate the concepts.

CCS is moving forward very slowly in Europe, and one reason is the lack of economic incentives for stimulating demonstration and early commercialisation. Another reason is lack of public awareness of CCS as a safe and efficient tool for combating global warming.

Presentation from the Tees Valley Combined Authority showed how important support from local authorities is to drive CCS forward. Tees Valley represent a very interesting case for industrial CCS and this is one of the most promising cases for CCS in Europe. The project would not have been as developed as it is without the proactive role local authorities have taken. Similar initiatives are needed from authorities all over Europe to ensure fast CCS deployment.

2.5 Parallel workshop 2 - Bringing CCS into new regions - developing countries

This workshop, co-organized by BGS and GEUS, has been one of major side event of the Open Forum 2017. It focussed on the potential role for CCS in climate mitigation for countries in developing regions. There were five presentations with country or regional specific views and experience around CCS.

After the introduction by Ceri Vincent (BGS), Joseph Essandoh-Yeddu (Energy Commission, Ghana) presented on implementing CCS in Africa, focused on Sub-Saharan Africa (south of the Sahara Desert). Joseph pointed out in his key messages that in Africa, as elsewhere in the world, more awareness is needed and that public support for CCS is essential. CCS is commonly seen as a high-tech solution for advanced countries and not considered by developing countries. CCS is still not a part of the African countries TNAs (Tech needs Assessments) under UNFCCC. CCS is, to large degree missing in the TNAs and NDCs (Paris Agreement, Nationally Determined Contributions) of African countries, except for a few in the Maghreb region and South Africa. In order to bring CCS into the picture, we need to look at drivers that are important for developing countries and choose market friendly titles such as “Assessing the Opportunities for improving oil and gas production in Africa using CO₂-based Enhanced Oil and Gas Recovery Technologies whilst concurrently mitigating GHG emissions”. The goal is assessing the Potential for CCS in Africa.

Felicia Mogo (Marine Environment Management, Nigerian Maritime Administration and Safety Agency (NIMASA), Nigeria) gave a country specific presentation on CCS in Nigeria: The Journey so Far. Nigeria has a goal of reducing greenhouse gas emission by at least 25% by 2020 to meet national and international obligations on environmental protection and to reduce the country's carbon footprint. The Vision 20:2020 envisages a rapidly growing economy with a significant increase in energy demand and gas flaring which alongside a large population means that emissions will increase significantly unless mitigated. Gas flaring from the petroleum sector in Nigeria produces over 100 million tons of CO₂ annually. Nigeria has acquired a great deal of data during oil exploration, including geological maps, geochemical and geophysical data and core logs that can be used to model the subsurface to the depth of 3 km or more. A small CCS team in Nigeria including NIMASA, the Federal ministry of environment, Nigerian National petroleum co-operation (NNPC), Nigerian content and monitoring board (NCMD) and the Geological survey of Nigeria are working on finding the best solutions to promote CCS and EOR in Nigeria. This includes prioritizing areas for CCS activities, stakeholder engagement to create advocacy for CCS, data gathering on state of the art CCS developments R&D CCS projects in Nigeria, development of a legal and regulatory framework, development of CO₂ infrastructure and incentives from the Government for the implementation of CCS. A “one-stop-shop” database is needed. CCS in Nigeria is

likely to create 100,000 jobs and to reduce the health impact from gas flaring and protect the environment from acidification.

Jonathan Pearce (BGS, UK) presented on the “Growing Opportunities for CCS in India”. India has the third largest economy in the world which is still growing rapidly. Rapid urbanisation and increasing income result in increasing energy demand. The National Action Plan for Climate change calls for a 20-25% reduction in carbon intensity by 2020. In order to meet this target, in the context of a growing economy and the continued need for increase in standard of living (including access to electricity), low carbon options are needed. “Since fossil fuel will occupy a major part of energy mix to at least 2047, there is no climate friendly scenario in the long run without CCS” (India Energy Security Scenarios, NITI Aayog, 2014). Utilisation of CO₂ is of interest to meet energy demands. The high cost of capture remains a barrier to a CO₂ market in India. A regional picture of the CO₂ storage potential was published by IEAGHG 2008/2 (contributors BGS and local technical institutes and consultants) which indicated possible regions for storage based on published data. This study highlighted the need for more data to carry out a full assessment. It was estimated that oil, gas and coalfields could store up to 5 years’ worth of emissions, saline aquifers had unquantifiable but potentially large storage volume. An assessment of the CCS potential in India was carried out by The Energy and Resources Institute for GCCSI (2013). This report indicated that barriers to large scale CCS included that deployment in India was likely to happen after deployment on a global scale, the need for more geological data, that EOR potential in India may be limited and lack of access to (international) finance. The GCCSI report also highlighted the need for capacity development for key stakeholders (policy makers, regulators, the general public, etc.) and technology transfer. The main conclusions of this presentation were that the CCS potential in India is being considered at all levels (future energy scenarios, industrial companies, innovators) but that storage potential is not fully defined yet and that new storage types may play a role.

Júlio Carneiro (University of Evora, Portugal) gave an overview of CCS Opportunities and Challenges in the Community of Portuguese Language Countries: Mozambique, Angola, Equatorial Guinea, East Timor and Cape Verde. The Community of Portuguese Language Countries (Portuguese: Comunidade dos Países de Língua Portuguesa - CPLP), is an intergovernmental organization across four continents, where Portuguese is an official language. CPLP cooperates in all areas, including CCS as it also part of the Clean Development Mechanism (CDM) under the Kyoto Protocol. The cooperation has worked on mapping capture opportunities from the energy and industrial sector, and mapping storage prospects. Most CPLP countries considered depleted oil and gas fields and onshore and offshore basins. Opportunities for storage in coal seams were studied in one country and a few countries had some opportunities for storage in volcanic rocks. Angola, Equatorial Guinea and Mozambique seemed to have the best opportunities for storage, but more work is needed to really assess potential. Angola, Equatorial Guinea and Mozambique all had large fossil fuel reserves and growing construction sectors with cement manufacture expected to contribute to increasing emissions. These three countries also have high biomass potential. Challenges included the unclear business case for CCS in developing countries, lack of knowledge transfer programmes, absence of studies addressing potential economic value for EOR in CPLP countries and the fact that no studies are available on the role for CCS in national climate change mitigation plans for CPLP countries. Drivers for CCS and the way forward for the CPLP countries includes raising awareness, looking for opportunities using EOR (Angola and Equatorial Guinea), assessment of CO₂ storage capacity and the observation that most African members of the CPLP and East Timor are usually listed as among the most vulnerable countries in the world to climate change.

New Projects in South Africa were presented by Nigel Hicks (Council of Geosciences (CGS), South Africa). The CGS has been active in CCS research for almost a decade having worked in various national research projects together with

South Africa National Energy Development Institute (SANEDI) who lead the South African Centre for CCS (SACCCS). The South African path towards CCS started in 2004 with mapping the CCS potential of South Africa followed in 2010 with preparation of the South African Storage Atlas. There are several large point sources including synfuel plants and new power stations that will contribute to increasing CO₂ emissions. Now in 2017, work is focusing on the SACCCS Pilot Carbon Dioxide Storage Project (PCSP), the third milestone in the South African CCS Roadmap. The pilot involves storage and monitoring of 10,000 – 50,000 t CO₂. The primary aims of the PCSP are to demonstrate safe storage of CO₂ in South Africa, increase human and technical capacity and to raise awareness of the potential importance of CCS amongst the South African public. Regions in the Eastern Cape are possible locations for the PCSP. Following on from the pilot project, the next steps on the South African CCS Roadmap are up-scaling to demonstration scale and implementation via commercial projects. Future work at the CGS to support the CCS Roadmap will likely include further basin-scale analyses of the remaining offshore basins to support new CCS projects. SACCCS has a Bursary programme to provide Honour, Master and Doctorate studies on CCS topics to build national capacity in South Africa. SACCCS also has a non-bursary funding programme to support CCS research projects.

Panel Discussion and Summary

Only a few developing countries recognise CCS as an essential and possible mitigation option. The main priority in developing countries is to improve living conditions for the population. CCS can support socio-economic development while limiting impact on the climate. CCS projects will look different in different regions of the world. Local drivers and incentives (e.g. job creation) are extremely important. For instance, in Africa, where less than 60% of the population has access to the national electricity grid, the approach should be quite different from European one. CCS projects and other new technologies must create jobs to boost local/national economy and bring benefits to society in order to satisfy the climate and socio-economic needs of the stakeholders. CCS development requires better geological assessments and mapping of potential storage capacities and creates opportunities for carbon trade.

We must support developing countries in considering CCS as a low carbon technology through raising awareness, undertaking knowledge sharing activities, capacity building and technology transfer. Onshore pilots (the key aim of ENOS project) are needed to pave the way for demos and full-scale projects. The lack of CCS activities in the most of development countries reflects the lack of drivers for deploying the technology.

2.6 ENOS open workshop 1 - Experience sharing focus groups: framing the topics

In the ENOS project, knowledge sharing is an important activity, as lessons learnt in previous and on-going pilots should be considered for enabling new onshore applications of CO₂ geological storage. One of the platforms for knowledge sharing will be experience sharing focus groups, where a list of specific topics will be discussed in webinars and workshops. These webinars and workshops will be not only open to ENOS partners but to anyone interested in the topic. In Venice, this first workshop was a good occasion to discuss the topics of interest, and start to prioritize them taking into account what ENOS project could achieve. The workshop was mainly attended by ENOS researchers with international partners (mainly from the US) who showed great interest in this action and were ready to collaborate in these groups.

After an introduction, the workshop was organized in two main parts: the objective of the first part was to propose potential topics of interests and was named “In what areas could developing European onshore pilots could learn from international experience? Ideas for future topics.” There, participants were asked to openly propose topics, as part of an organized brainstorming. This led to very interesting discussions as proponents had to justify why their proposition was important. The diversity of topics was important as it ranged from “data management” to “improved injectivity” or “engagement with population”.

In the second part of the workshop, it was time to re-arrange and prioritize the material that was accumulated in the first part. An important aspect was also to figure who could lead the topics and present a webinar about it.

The first webinar, which is tentatively scheduled in September 2017 will be around the issue of data management and archiving. Among the other topics discussed of top priority were public engagement, site characterisation and site monitoring. This last topic will possibly be tackled as a workshop as part of a future Open Forum in Venice.

2.7 ENOS open workshop 2 - Research priorities and future pilots

The workshop started with the discussion around possibilities of developing practical research projects in the near future. The first option are the small-scale projects for CO₂ storage that are scalable to test storage in specific locations and geological settings; the second option are the pilot projects *sensu stricto* which are more focussed on R&D problems while they could also have a role to play in supporting wider deployment. Both types will be referred to as the pilot projects.

First part of the workshop aimed to define the R&D questions that new pilots could address, and in this way to streamline development plans by definition of three generic pilots that address key questions to further enable storage. Three broad topics were discussed: Site design and operational flexibility, Optimizing strategic reserves and Assuring site conformance. Several common issues were defined in each of these topics. Those are: that subsurface conditions are such that both the inter-granular porosity and dual porosity situations will surely be encountered, that it is not only the depleted hydrocarbon reservoirs that should be considered but also some of the fields that are still in production, and in the end that there are the two types of saline aquifers - open and closed, and there are important differences in testing these potential storage objects.

The first topic - **Site design and operational flexibility** - was detailed in terms that much will have to be done in improving storage capacity estimation and that is was not done enough in explaining the differences between regional versus site-specific seal properties. Second important aspect is really a practical one: storage must operate with variable CO₂ supply, which means that a need for flexibility in infrastructure simply can't be overestimated.

The second topic - **Optimising use of strategic reserves** - resulted in discussion of the possible synergy with enhanced hydrocarbon recovery operations and how could this be achieved in collaboration with a commercial operation. There were many questions raised regarding the pressure management opportunities and water disposal, in particular in the stacked aquifers of closed structures; after that on water co-injection & mixing and on the plume steering (practical tests needed). One of the closing remarks of this part was that an aim should be to thoroughly study near-wellbore impacts and connected effects of long-term injection.

The third topic - **Assuring site conformance** - took us to a lengthy discussion of the issues that were not much considered before. The first one was the importance of induced seismicity as a research topic for a storage pilot. Second subtheme was the seal integrity and hysteresis following depletion – topic important to the oil and

gas reservoirs, both that are depleted or are still in production phase. This lead to the remarks on pressure reduction options which depend on the local geology.

The concluding part of the workshop, after the break, was oriented to definition of the three concepts for future “generic pilots”, meaning that neither the number of each type nor the location is defined, only their possible (wanted) characteristics. Everything will in the end depend on the results of screening/evaluation.

Enhanced hydrocarbon pilot will be linked to HC production and this presents at first the challenges of working in commercially-operated field and challenges of mining regulations and liabilities. There was a suggestion that such a project might include actual reviving of an abandoned field (e.g. the Vienna Basin LBr-1 pilot of ENOS) but this remains to be seen if possible due to costs. Technical issues summed up to the pressure maintenance (for indirect EOR), buffer storage requirements to cope with fluctuating delivery (and/or variable injection scheme) and again on the seal integrity and hysteresis issues (geochemical and geo-mechanical properties and changes). There were suggestions for testing the pore-scale migration processes through micro-fractures in seals and reservoirs and also for the new methods for well construction and completion. Uncertainties and problems were identified in the possible stream composition variability and challenges of multiphase, multicomponent modelling of fluid behaviour. The question of defining “efficiency” in EOR+CCS was raised. In the end, it was concluded that all existing petroleum production projects by default offer certain public engagement opportunities (for demonstration of a durable technology to both interested and positively inclined local population).

CCS + geothermal & energy synergies was the second generic pilot. This is regarded to be important due to connections with several aspects - CO₂ dissolved concept (for niche areas – small flows), CO₂ storage and heat production, CO₂ storage and energy storage, combination of power-to-gas with CCS, as well as situations where H₂ production from fossil fuels gives large pure CO₂ streams. The problems were identified primarily in the gaps in our current capacity mapping for smaller-scale geothermal projects but all mentioned combined projects have potential to be excellent public dialogue opportunities. Another challenges may also be expected (e.g. induced seismicity).

Flexible storage designs were grouped in the third generic pilot. This would include the stacked stores (vertically stacked reservoirs) in every location of favourable local geology, innovative injection concepts and well designs that might (and surely will) be optimised. What would be new for such proposals is that balancing injection across different horizons will become an issue together with the existing ones - impacts close to wellbore versus impacts on seals, plume steering and pressure maintenance. Another challenge is that a geologically complex site would need adapted and flexible monitoring systems and most probably very careful definition(s) of storage complex(es). Common issues with other pilots lie in redundancy for supply and compositional variations, challenges over cost versus value and risk and, as usual the upfront capital investment requirements and long-term revenue. Based on the projects active so far, a staged approach is one of the things that are looked at as the only way to overcome these problems.

2.8 Young researchers' networking event

Two events were specifically dedicated to young researchers during the Open Forum.

Training and capacity building represents one of the four areas of activity for CO₂GeoNet to position itself as a reference body for European science on CO₂ Geological Storage. The strategy includes training and capacity building and

specifically fostering the upcoming generations of scientists that will be needed for the deployment of the technology.

As part of this strategy, CO₂GeoNet planned the first event for young researcher (PhDs and Post docs) at this Venice Open Forum. The event comprised both a poster session for the young researchers to present their scientific work in the CCS area during the Open Forum Icebreaker and a session on the third day on carrier planning and networking.

The **Poster session** engaged all the participants at the Icebreaker event to vote for the best poster. The prize for the best poster went to David Rukavina (UNIZG-RGNF).

The **Workshop 'Young researchers' networking event'** aimed at giving young researchers an opportunity to discuss how to develop a network within the CO₂GeoNet Association, plan one's career and find a future dream job. It also gave an introduction to the Erasmus Mundus Program, and to the ENOS project's activities dedicated to education at university MSc level and further training through e-learning books and spring schools (starting in 2018).

3 Event visibility

3.1 Announcements and on-line news

The CO₂GeoNet Open Forum 2017 and ensuing workshops have been advertised through a series of announcements, sent by e-mail to about 1.800 recipients.

Information about the incoming event have been posted in the websites of co-organisers and endorsers and circulated through on-line weekly news, as shown, for example in Figure 1.

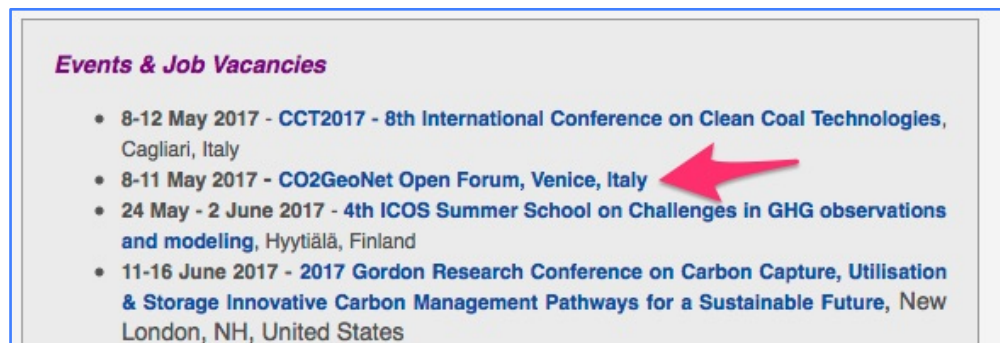


Figure 1 The Open Forum advertised by the IEAGHG Weekly News of 28 April

3.2 Open Forum website

As for the past editions of the Open Forum, a dedicated website has been developed for the conference (<http://conference2017.co2geonet.com>), see Figure 2.



Figure 2 The CO₂GeoNet Open Forum website



Figure 3 Indication of collaborations and conference endorsements

After the conference, all the presentations held during the Open Forum and the four following workshops have been uploaded in the website, together with short interviews to the session chairs, as shown in Figures 4-6.

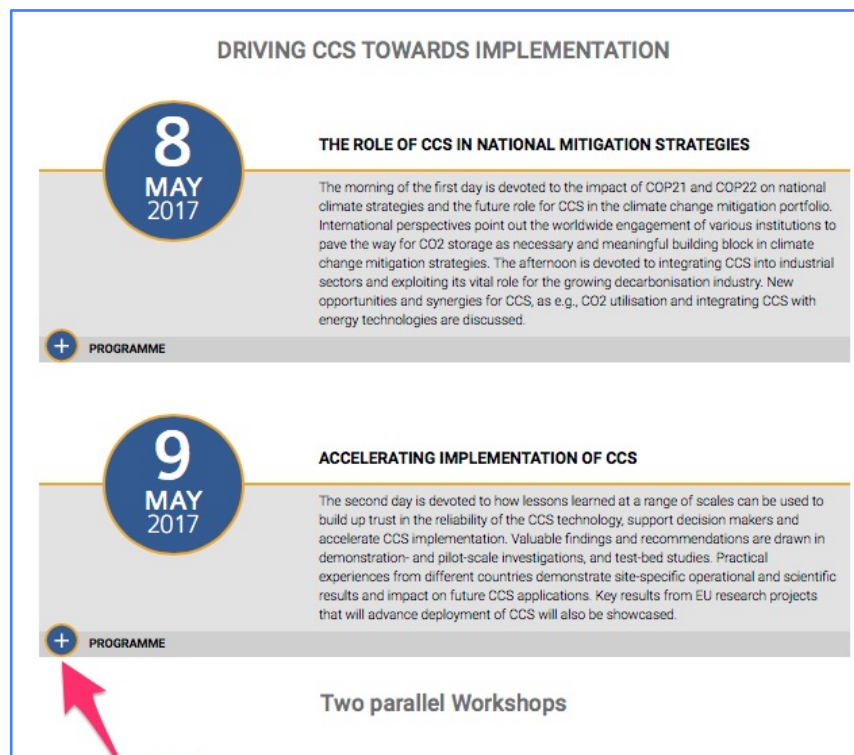


Figure 4 Days of the various events. By clicking below each date (red arrow) the corresponding programme appears



Session 5 Accelerating Implementation of CCS	
 <i>Chair: Marjeta Car, CO2GeoNet-GEO-INZ & Franz May, CO2GeoNet-BGR</i>	
13:45 - 14:05	Highly Controlled CO2 Injection Experiments at Heletz (Israel) <i>Jacob Bensabat, EWRE Ltd., Israel</i> SLIDES
14:05 - 14:25	IMPACTS – CO2 Quality and CCS System Design and Performance <i>Ton Wildenborg, CO2GeoNet-TNO, The Netherlands</i> SLIDES
14:25 - 14:45	CO2 Storage Activities in Greece <i>Nikolaos Koukoulas, CO2GeoNet-CERTH, Greece</i> SLIDES
14:45 - 15:05	The Rotterdam Nucleus - a Pilot Case for CO2 Transport Infrastructure <i>Marie Bysveen, CO2GeoNet-Sintef, Norway</i> SLIDES
15:05 - 15:30	 Panel Discussion

Figure 5 Programme of Session 5, on May 9. Arrows red and blue indicate where to click for the interview and presentation slides

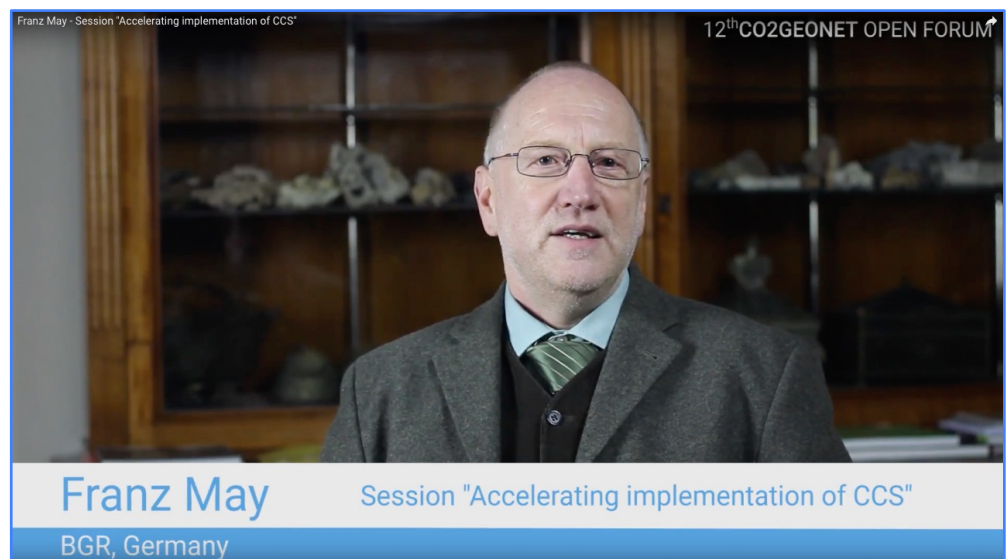


Figure 6 Interview initial frame. After few seconds, the footer disappears

3.3 Press release

On May 23, the following text has been produced to summarise the 2017 Open Forum. The text was sent to the Open Forum attendees and to the ENOS and CO₂GeoNet members, asking them to translate it into their national languages to be used in their contacts with journalists.

Press Release

Driving CCS towards implementation

From 8 to 11 May 2017 almost a hundred stakeholders and scientists met at the CO₂GeoNet Open Forum in Venice to present and discuss the latest status of CO₂ Capture and Storage (CCS) and actions needed to implement this climate mitigation technology at industrial scale. Representatives from many European countries as well as from further abroad including the USA, Australia, Africa and Asia attended.

Achieving the CO₂ emission reduction required to keep the temperature increase well below 2 °C (in line with the Paris Agreement) requires rapid and far-reaching actions. Most scenarios rely on massive deployment of CCS to realise at least 15% of the needed emission reductions in 2050. In the 2nd half of this century negative emissions through use of biomass and direct capture of CO₂ from the air will be needed to achieve the necessary emission reduction in the longer term.

CCS is a proven technology: Large scale-demo projects are already running in countries such as Norway (1996), Canada (2000) and the USA (2004). Smaller-scale/pilot projects can also play an important role in improving the engineering design of large-scale CCS projects and refining various aspects of the technology. Moreover, pilot projects allow people to better understand the technology and to recognize it as a climate change mitigation action. CCS technology is developing at varying rates in different regions of the world.

Developing regions such as Africa are often interested in how new low carbon energy technologies can help achieve higher levels of economic growth with creation of jobs and wider access to low-cost electricity, while avoiding greenhouse gas emissions. In most African countries less than 50% of the population has access to electricity and so the need for higher levels of electrification must be considered when developing energy infrastructure for the future. CCS could have a very prominent role to play in developing regions.

Adjacent to the Open Forum, CO₂GeoNet co-organised workshops in collaboration with international partners on 'Fit-for-Purpose Solutions for CCS' (IRIS and Gassnova) and 'Bringing CCS into new regions – developing countries' (BGS and GEUS). In cooperation with partners of the ENOS project, workshops were held to identify topics of common interest for knowledge sharing focus groups and research priorities for future pilot/small scale storage projects.

Capacity building is needed to facilitate the large-scale deployment of CCS. This is one of the core areas of activity for CO₂GeoNet. This year, the Open Forum included special events for young researchers to present their results and to build up a network. Engaging young researchers earlier in their career would offer them a faster start and increased contribution to the development of CCS technology. Bright young minds who took part in the Open Forum capacity building event are working on various areas including the evaluation of storage capacity and economics of the CCS technology.

The outcomes of the 12th CO₂GeoNet Open Forum, including a short report, presentations and videos of speakers, are being uploaded at <http://conference2017.co2geonet.com/>.

About CO₂GeoNet

CO₂GeoNet is the European scientific body on CO₂ geological storage. The Association currently comprises 28 research institutes from 21 European countries, and brings together over 300 researchers with the multidisciplinary expertise needed to address all aspects of CO₂ storage. With activities encompassing joint research, training, scientific advice, information and communication, CO₂GeoNet has a valuable and independent role to play in enabling the efficient and safe geological storage of CO₂. CO₂GeoNet was created in 2004 as a Network of Excellence supported by the EC FP6 programme for 5 years. In 2008, CO₂GeoNet became a non-profit Association under French law. From 2013 onwards, the membership of CO₂GeoNet expanded thanks to the support of the now completed FP7 CGS Europe project. The Association continues to grow with the acquisition of new Members, which indicates that the European scientific community continues to recognize the role for CCS in the future of Europe and the need to refine the technology through continual innovation and development.

More about CO₂GeoNet at <http://www.co2geonet.com/>

Members of CO₂GeoNet:

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4 Results and key messages

The following key messages emerged at the CO₂GeoNet Open Forum 2017, during the presentations, the interesting discussions and the works of the various break-out groups. They may be considered as the more meaningful result of the international conference.

OF2017 - KEY MESSAGES

CCS DEPLOYED ON A GLOBAL SCALE IS ESSENTIAL FOR ACHIEVING THE COP21 OBJECTIVES

As the targets of the Paris Agreement are translated into actions by countries worldwide, the need for large-scale deployment of CO₂ Capture and Storage (CCS) will become even more apparent. The 12th CO₂GeoNet Open Forum focused on driving CCS towards implementation the critical role that CO₂ storage is ready to play in climate change mitigation strategies to achieve crucial low carbon targets.

No success without CCS

It is essential to act quickly: the carbon countdown is ticking ([carbon brief 2016](#)). Globally, we're currently on track to overshoot our target for keeping global temperature rise below 2°C and are heading for a global average temperature increase well beyond 4°C. Even if all policies currently in place or proposed are enacted, we are still facing a temperature increase close to 3°C. Mitigation costs are expected to be more than double for the 2° C scenario (2°S) if CCS is not deployed.

We only have four years left in which to reach neutral CO₂ emissions if we want to achieve the 1.5 scenario (1.5°S). Not emitting CO₂ into the atmosphere, which is the aim of the majority of emission reduction technologies, is no longer enough: to meet the Paris Agreement, negative emissions, i.e. a net removal of CO₂ from the atmosphere, will be necessary even to meet the 2°S. The need for negative emissions indicates there is a huge role for bioenergy coupled with CCS (BECCS) and emerging technologies such as direct removal of CO₂ from the air. BECCS has been demonstrated at industrial scale, and will be needed to compensate for the lack of progress in reducing emissions over the past decades.

How to break the current inertia and get things moving

Lack of progress in implementation of CCS at large scale indicates the need for greater engagement with a broader group of stakeholders. In order to move CCS forward, it is essential to 'leave no one behind'. Better engagement with the financial and insurance sectors, regulators, policy makers, thought-leaders and the general public is required. The language used is also very important; messages need to be understandable for strategic planners, politicians, economists etc. CCS projects designated by more business- and market-friendly titles and themes would attract more attention (e.g. 'low carbon solutions' highlighting examples of good practices worldwide, emphasising benefits for the local community and business etc.).

CCS has progressed over the last two decades, but has not yet reached its full potential to reduce emissions. The portfolio of CCS projects running has diversified, with an increasing variety of projects coming to fruition. However, there seems to be a lack of projects in the pipeline, which could lead to stalled progress.

What can we do about this in the immediate future?

- Get small-scale projects going that can de-risk storage formations enabling later up-scaling
- Seek synergies with low carbon technologies outside CCS, e.g. geothermal and biomass with CCS pilots - this targets businesses outside the CCS community and facilitates development of carbon-negative businesses in the case of biomass
- Decouple the CCS chain into capture and transport, and storage infrastructure using hubs (collection and multiple stores) to help share the financial burden and risks
- Provide 'storage ready' ('plug and play') solutions for emitters to utilise storage sites
- Develop tailored solutions for small industrial installations to meet their specific requirements. A flexible decoupled network could connect small emission sources
- Deploy CCS at industrial sources where pure or high-concentration CO₂ is emitted (cement and hydrogen production, etc.). This offers considerably lower capture costs which helps strengthen the business case. However, a mixture of capture options including retrofitting, oxyfuel etc. need to be considered as CCS needs to be applied to a wide range of sources
- Seek utilisation opportunities as an enabler for storage and cooperation, e.g. organise regional CCUS coordination bodies (market makers) in CO₂ intensive industrial areas, which will then oversee optimal matching of shared infrastructure. Their role should also help share the cost burden and organise a coalition to seek funds in the EC.

Stable policy support is essential

A stable policy framework is critical for implementation of CCS and wider community engagement. Policy support has fluctuated over recent years (2009-2015) and is now rising again. An enormous leap is needed within just one generation in terms of volumes of CO₂ stored: from 40 Mt/y to 4000 Mt/y to achieve the 2°S. Therefore, it is crucial to convince policy makers and the public on the role for CCS. Thus far, only around 10 Nationally Determined Contributions (NDCs) include CCS, and all the national commitments will not allow us to achieve the Paris Agreement targets: a clear and consistent message is needed from all involved stakeholders both within and without the CCS community; CCS is needed and now. The benefits and advantages of CCS also need to be clearly demonstrated and explained.

It is also essential that CCS gets the same backing and 'image' as other clean energy technologies, such as renewables, this is about policy parity. Over the last 20 years, investment in renewables has outweighed investment in fossil fuels. CCS needs similar consideration based on the equally crucial role for CCS in a low carbon future. Current financing mechanisms are not yet strong enough to drive implementation and this needs to be communicated to policy makers. Investment of public funds in CCS has been shown to have a strongly positive effect in leveraging larger investments from the private sector. Member States should initiate

infrastructure and possibly storage to accelerate implementation. Targeted deployment incentives are needed (capital and operation).

Stable policies and establishing an effective business case is urgent. Without this, implementing CCS represents a high risk for the operator. Increased uncertainty increases the cost of projects, decoupling the CCS chain is therefore expected to encourage investors (e.g. storage operators will not be penalised for issues with the capture plant).

Bringing CCS to new regions of the developing world

Only a few developing countries recognise CCS as an essential mitigation option. The main priority in developing countries is to improve living conditions for the population. CCS can support socio-economic development while limiting impact on the climate. CCS projects will look different in different regions of the world. Local drivers and incentives (e.g. job creation) are extremely important. For instance, in Africa, where less than 60% of the population has access to the national electricity grid, the approach has to be totally different than in Europe. CCS projects and other new technologies must create jobs to boost local/national economy and bring benefits to society in order to satisfy the climate and socio-economic needs of the stakeholders. CCS development requires better geological assessments and mapping of potential storage capacities and creates opportunities for carbon trade.

We must support developing countries in considering CCS as a low carbon technology through raising awareness, undertaking knowledge sharing activities, capacity building and technology transfer. Onshore pilots are needed to pave the way for demos and full-scale projects.

CCUS is only acceptable if it ends with “S”

Without storage, CO₂ use in most cases does not contribute significantly to decarbonisation. CO₂ use is an enabler technology to help build a CCS economy but on its own will not solve the anthropogenic emission problem. Various studies agree that the use of CO₂ can only account for 2-4 % (at best) of total yearly CO₂ emissions (current CO₂ market equivalent to 0.5 % of annual emissions).

Carbon dioxide Capture Utilisation and Storage (CCUS) can help build a CO₂ economy and engender a more positive image for CCS through providing environmental, economic and societal benefits (i.e. using waste from one plant to provide feedstock for another). Replacing CO₂ feedstock sourced from natural accumulations with anthropogenic CO₂ leads to emission reduction and could be a small step towards a CO₂ economy. CO₂ should not be considered as a waste, but as an asset. Synergistic activities including utilisation of CO₂ can help advance storage and storage sites (e.g. reservoir performance prediction). Instead of EOR, we should be talking about EOR+, i.e. EOR with maximised CO₂ storage. Coupling CCS with EOR seems to be particularly appealing option for some developing countries.

EU regulations on use of CO₂ are not yet in place. However, the European SET Plan Action 9 includes targets for CCS and CCUS to help kick-start a CCS economy. Targets for the SET plan and the EU Research and Innovation agenda include a full-scale CCS project in Europe linked to an industrial source, delivery of the ROAD project (CCS on a power plant including CO₂ utilisation by greenhouses), regional CCS clusters (Norwegian industrial CCS cluster, Port of Rotterdam CO₂-

hub, North-East UK CCS cluster, etc.), Projects of Common Interest, a European Storage Atlas and small scale/pilot CCS and CCUS projects. The intention is that actions will be driven forward by Member States.

Learning by doing is essential: Pilot/small scale projects are part of the process

Current research shows test beds, pilots and demo projects are performing as originally planned – no major deviations have been observed to date - this confirms that CCS projects can be managed safely and that CCS is ready to be implemented at industrial scale. Experience is key to better planning, reducing time spent on site design and construction, optimising costs and more effective public engagement. Lessons learned from demonstration projects such as Boundary Dam will allow significant reductions in cost for the next generation of CCS projects. Research to refine issues that are identified through these first generation demonstration projects are also needed.

Collaboration on research is a positive step toward optimisation of research infrastructure and contributes to maximised utilisation and development of expertise. An example of this is ECCSEL which draws together European CCS facilities and enables access to a unified research infrastructure to the CCS research community.

Pilot projects are key in reducing storage site monitoring costs and represent excellent communication opportunities to prove the safety and sustainability of CCS operations to regulators and the general public.

Over the years, numerous pilot and demo projects have been launched/finished – a comprehensive analysis on what went well and what did not would be noteworthy information for the future deployment of CCS. This will be prepared through the ENOS project, an initiative of CO₂GeoNet funded through the H2020 programme. For more information please visit our website www.enos-project.eu

Appendix 1 - The Programme



12th CO₂GeoNet Open Forum

May 8-9, 2017

Driving CCS towards implementation

May 10, 2017

Side event co-organized by IRIS and Gassnova

Fit-for-purpose solutions for CCS

Side event co-organized by BGS and GEUS

Bringing CCS into new regions - developing countries

ENOS Open Workshop organized by BRGM

Experience sharing focus groups: framing the topics

Young researchers' networking event

May 11, 2017

ENOS Open Workshop organized by BGS and RGNF

Research priorities and future pilots

CO₂GeoNet - a resource for Europe providing scientific support for the geological storage of CO₂

CO₂GeoNet - an Association of 28 members over 21 countries

The Forum - to make scientific research and researchers available to stakeholders

Venice, San Servolo Island, Italy



Organized by CO₂GeoNet in collaboration with:



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Through the EU funded Horizon 2020 project ENOS, a CO₂GeoNet initiative



European Technology Platform for Zero Emission Fossil Fuel Power Plants



AGENDA

Monday May 8 - The role of CCS in national mitigation strategies

8:30 Registration

9:00 Welcome

Sergio Persoglia, CO₂GeoNet Secretary General

9:05 Objectives of the 12th CO₂GeoNet Open Forum

Ton Wildenborg, President of CO₂GeoNet

Keynote Talk – Setting the scene

Chair: Ton Wildenborg, CO₂GeoNet-TNO & Aage Stangeland, Research Council of Norway

09:15 After 20 years - can CCS reach its potential?

Niels Berghout, IEA Energy Analyst - CCS Unit, France

10:00 Panel discussion

10:15 Coffee break

Session 1: Meeting the COP targets - worldwide engagement

International perspectives on the impact of the Conference of the Parties

Chair: Isabelle Czernichowski, CO₂GeoNet-BRGM & Manfred Treber, Germanwatch

10:45 The role of CCS in delivering the Paris Agreement

John Scowcroft, Global CCS Institute, Executive Adviser Europe

11:05 Summary and status of major CCS research, development and demonstration projects in the United States

Thomas Sarkus, NETL US-DOE, USA

11:25 Engagement in Africa

Joseph Essandoh-Yeddu, Energy Commission, Ghana

11:45 European industries, reconciling employment and climate action

Keith Whiriskey, Climate Technologies, Bellona Foundation

12:05 Panel discussion

12:30 Lunch break

Session 2: Decarbonising industry - the vital role of CCS

Integrating CCS into the industrial sector

Chair: Ceri Vincent, CO₂GeoNet-BGS & John Scowcroft, GCCSI

13:45 Tomakomai CCS Demonstration Project

Yoshihiro Sawada, Japan CCS

-
- 14:05 European Commission initiatives on CCUS**
Vassilios Kougionas, DG Research & Innovation, European Commission
- 14:25 Needs in research and development for CO₂ usage and valorization**
Gabriel Marquette, The National Centre for Scientific Research, CNRS, France

14:45 Panel discussion

15:15 Coffee break

Session 3: New opportunities and synergies for CCS
CO₂ utilization and integrating CCS with energy technologies
Chair: Conny Schmidt-Hattenberger, CO₂GeoNet-GFZ & Thomas Sarkus, NETL US-DOE

- 15:45 A new paradigm for CCS – carbon utilization for subsurface energy resource management**
Srikanta Mishra, Battelle, USA
- 16:05 Making CO₂ sequestration affordable by coupling it with geothermal energy extraction**
Martin Saar, CO₂GeoNet-ETH Zürich, Switzerland
- 16:25 Near term deployment opportunities for Bio-Energy with CCS (BECCS) to meet Paris Agreement mitigation targets**
Henrik Karlsson, Biorecro, Sweden
- 16:45 CO₂ utilization in the industry - overview, prospects and recommendations**
Valérie Czop, Club CO₂, France

17:05 Panel discussion

- 17:25 Closing remarks Day 1**
Ton Wildenborg, President of CO₂GeoNet

From 18:00 Icebreaker evening and poster session
San Servolo Island - Room Basaglia

- 18:10** Niels Poulsen, CO₂GeoNet-GEUS, Denmark: **Welcomes young researchers**

Young researchers (PhD and PostDoc) present their scientific work in a poster session at the Icebreaker evening.

In parallel: **Advisory Committee Meeting**

Tuesday May 9 - Accelerating implementation of CCS

8:30 **Welcome and introduction**
Sergio Persoglia, CO₂GeoNet Secretary General

Session 4: Lessons learned for future applications

Building on practical experience (test bed - pilot - demo scales)

Chair: Roman Berenblyum, CO₂GeoNet-IRIS & Kari-Lise Rørvik, Gassnova

08:35 **Quest - industrial CCS in action**
Owain Tucker, Global CCS Deployment Shell, UK

08:55 **The Otway stage 3 project – low impact, fit for purpose monitoring & verification**
Max Watson, CO₂CRC, Australia

09:15 **Current CCS research and development activities and major demonstration projects in Japan**
Ziqiu Xue, RITE Kyoto, Japan

09:35 **Small scale field test demonstrating CO₂ geologic storage in Arbuckle saline aquifer and CO₂-EOR at Wellington field in Southern Kansas**
Evgeny Holubnyak, Kansas Geological Survey, USA

09:55 Panel discussion

10:15 *Coffee break*

Session 4: Continued

Chair: Niels Poulsen, CO₂GeoNet-GEUS & Vit Hladik, CO₂GeoNet-CGS

10:45 **The Ketzin pilot site – post-injection and abandonment phase**
Conny Schmidt-Hattenberger, CO₂GeoNet-GFZ, Germany

11:05 **Hontomin Technology Development Plant - from characterization to injection**
José Carlos de Dios, CO₂GeoNet-CIUDEN, Spain

11:25 **Sulcis Fault Lab - preparation for drilling phase**
Sabina Bigi, CO₂GeoNet-La Sapienza, Italy

11:45 **Assessing monitoring technologies at the UK GeoEnergy Test Bed**
Ceri Vincent, CO₂GeoNet-BGS, UK

12:05 Panel discussion

12:30 *Lunch break*

Session 5: Accelerating implementation of CCS

Showcasing results from EU projects

Chair: Marjeta Car, CO₂GeoNet-GEO-INZ & Franz May, CO₂GeoNet-BGR

13:45 **Highly controlled CO₂ injection experiments at Heletz (Israel)**
Jacob Bensabat, EWRE Ltd., Israel

14:05 The Rotterdam Nucleus - a pilot case for CO₂ transport infrastructure
Marie Bysveen, CO₂GeoNet-Sintef, Norway

14:25 CO₂ storage activities in Greece
Nikolaos Koukoulas, CO₂GeoNet-CERTH, Greece

14:45 IMPACTS – CO₂ quality and CCS system design and performance
Ton Wildenborg, CO₂GeoNet-TNO, The Netherlands

15:05 Panel discussion

15:30 Coffee break

Session 5: Continued

Chair: Sabina Bigi, CO₂GeoNet-La Sapienza & Keith Whiriskey, Bellona

16:00 Implementation of the European CCS research infrastructure ECCSEL - experiences and remaining activities
Michela Vellico, CO₂GeoNet-OGS, Italy

16:20 An update on the ROAD project
Andy Read, Maasvlakte CCS Project C.V., The Netherlands

16:40 The Smeaheia site and its role in upcoming CCS projects
Kari-Lise Rørvik, Gassnova, Norway

17:00 Panel discussion

17:20 Closing remarks Day 2
Ton Wildenborg, President of CO₂GeoNet

17:55 Departure by boat to the Gala Dinner

Parallel WORKSHOP I: Fit-for-purpose solutions for CCS

Side event of the CO₂GeoNet Open Forum, co-organized by IRIS and Gassnova

Chairs: Aage Stangeland, Research Council of Norway & Kari-Lise Rørvik, Gassnova

09:00 Welcome and introduction

Roman Berenblyum, IRIS, Norway

09:10 Screening of potential sites on the Norwegian continental shelf

Kari-Lise Rørvik, Gassnova, Norway

09:30 Study of the BECCS potential in the Nordic countries

Timur Delahaye, BioRecro, Sweden

09:50 Drivers for CCS and industry – demand for low carbon products

Sarah Tennison, Tees Valley Combined Authority, UK

10:10 Coffee break

10:40 CO₂ DISSOLVED - an innovative CCS approach fitted to small industrial emitters

Christophe Kervevan, BRGM, France

11:00 Break-out group I: Does BECCS need large-scale CO₂ storage?

Break-out group II: Can low carbon products and involvement of small emitters influence CCS acceleration?

11:30 Summary from both groups & joint discussion

12:00 Lunch break

Parallel WORKSHOP II: Bringing CCS into new regions - developing countries

Side event of the CO₂GeoNet Open Forum, co-organized by BGS and GEUS

Chairs: Ceri Vincent, BGS & Niels Poulsen, GEUS

09:00 Welcome and introduction

Ceri Vincent, BGS, UK

09:10 Climate Technology Centre & Network (CTCN) - implementing CCS in Africa

Joseph Essandoh-Yeddu, Energy Commission, Ghana

09:30 CCS in Nigeria - the journey so far

Felicia Mogo, Nigerian Maritime Administration and Safety Agency, Nigeria

09:50 Growing opportunities for CCS in India?

Jonathan Pearce, BGS, UK

10:10 Coffee break

10:40 CCS opportunities and challenges in the community of Portuguese language countries - overview from Angola, Mozambique, Cape Verde and others

Júlio Carneiro, University of Evora, Portugal

11:00 New projects in South Africa

Nigel Hicks, Council for Geoscience, South Africa

11:20 Panel discussion and summary

12:00 Lunch break

Young researchers' networking event

Side event of the Open Forum, organized by CO₂GeoNet

Chair: Sabina Bigi, CO₂GeoNet-La Sapienza

13:30 Young researchers' networking event

Niels Poulsen, CO₂GeoNet-GEUS, Denmark

14:00 Presentation of Erasmus program

Sabina Bigi, CO₂GeoNet-La Sapienza, Italy

14:30 Closing remarks

Niels Poulsen, CO₂GeoNet-GEUS, Denmark

ENOS Open Workshop I - Experience sharing focus groups: framing the topics

Organised by BRGM for ENOS

All discussions led by Thomas Le Guéan, BRGM

13:30 ENabling Onshore CO₂ Storage in Europe (ENOS)

Roman Berenblyum, IRIS, Norway

14:00 Experience sharing focus groups and purpose of the workshop

Thomas Le Guéan, BRGM, France

14:15 Break-out group: In what areas could developing European onshore pilots learn from international experience? Ideas for future topics

15:15 *Coffee break*

15:45 Break-out group: Planning the experience sharing focus groups - what topics should be tackled in priority and how?

16:45 Wrap-up & preparation for next experience sharing focus groups event

17:30 Closing remarks

Thomas Le Guéan, BRGM, France

ENOS Open Workshop II - Research priorities and future pilots

Organised by BGS and RGNF for ENOS

All discussions led by Jonathan Pearce, BGS & Bruno Saftic, RGNF

09:00 Introduction and aims of the workshop

Jonathan Pearce, BGS, UK

09:20 Discussion session: future storage site design and operational feasibility

- Improving storage capacity estimation and management
- Flexible storage design

09:45 Discussion session: optimising use of strategic reserves

- Pore-space optimisation
- Maximising storage following EHR
- Improving controls on injectivity

10:15 *Coffee break*

10:45 Discussion session: assuring site conformance

- Maintaining seal rock integrity
- Improvements in monitoring technologies to lower cost and increase efficiencies
- Risk profiles for CO₂ storage and methodologies for site conformance
- Improved leakage mitigation technologies

11:45 *Lunch break*

13:00 Prioritisation of studies for three future pilot/small-scale projects based on morning discussion sessions to feed into EERA and ENOS deliverables

Jonathan Pearce, BGS, UK

13:15 Discussion and finalisation of workshop outcomes – prioritised research topics for three pilot / small-scale projects

Bruno Saftic, RGNF, Croatia

13:45 Closing remarks

Jonathan Pearce, BGS, UK

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