SCCS

Scottish Carbon Capture & Storage

SCCS Recommendations and Conference 2013 Report

Unlocking North Sea CO_2 Storage for Europe: Practical actions for the next five years

Credits and disclaimers

THE recommendations set out in this report have been identified by Scottish Carbon Capture & Storage (SCCS) as key steps that can be taken to unlock the North Sea as the leading destination for CO_2 storage in Europe. They draw on the presentations and interactive discussions from our annual conference in Edinburgh on 12 September, 2013, which was attended by policy makers and decision makers, regulators, representatives of industry and NGOs, and academic researchers. Our thanks to conference speakers and participants for their willingness to contribute fresh thinking, and to the colleagues and policy makers who subsequently helped us test policy options and refine these recommendations.

This report also serves as an overview of the high calibre of debate at the conference, and seeks to provide insights into European CCS policy and the practical opportunities for and barriers to CO_2 storage in the North Sea. Recommendations remain those of SCCS, and should not be attributed to individual speakers or conference participants.

More details of the conference can be found at **www.sccs.org.uk/conference2013**

Read our 2012 report *Central North Sea – CO_2 Storage Hub: Enabling CCS deployment in the UK and Europe*: **www.sccs.org.uk/cns-report**

About SCCS and our partners

SCCS is a research partnership of British Geological Survey (BGS), Heriot-Watt University and the University of Edinburgh. It is the largest carbon capture and storage research group in the UK. With internationally renowned researchers and state-of-the-art facilities, it is unique in its connected strength across the full CCS chain, providing a single point of coordination for all aspects of CCS research, ranging from capture engineering and geoscience to public engagement, policy and economics. SCCS is predominantly funded by the Scottish Funding Council, with contributions from the Natural Environment Research Council, BGS, Heriot-Watt University and the University of Edinburgh.

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A report published by Scottish Carbon Capture & Storage

ISBN: 978-0-9927483-0-2

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Executive Summary

CARBON dioxide emissions are the major cause of climate change: that is unequivocal. To limit the effects, we must reduce the amount of fossil carbon combusted and emitted as CO_2. Carbon capture and storage (CCS) is the only technology that directly reduces emissions at source, and enables countries to manage carbon budgets for both power plants and process industries. The next five years will be crucial in putting CCS back into position as an enabler of Europe's transition to a low-carbon economy. Practical actions must be combined with durable policy drivers to rebuild confidence and attract investment. This will be essential for large-scale emissions reductions from both industry and power generation to 2030 and 2050 as Europe seeks to manage climate risk, retain jobs and improve its low-carbon competitiveness.

The North Sea is the largest CO_2 storage resource in Europe, and offers the ideal location for immediate efforts. By using low-cost available CO_2 from industrial sources, Europe can accelerate the development of enabling infrastructures for CO_2 transport and storage. The following six recommendations set out steps that can be taken now to help unlock North Sea CO_2 storage for Europe.

POLICY CONTEXT

Recommendation 1: A strategic vision for CCS in 2030

› *Position CCS for deployment sufficient for EU industrial emissions and power generation*

CCS needs to be explicitly addressed in the European Union's 2030 framework for climate and energy policy, stating the scale of CCS deployment intended and, consequentially, the timescales for investments in the enabling infrastructures needed for CO_2 storage and transportation. The 2030 framework should place CCS equally alongside actions to support renewable power generation and energy efficiency as part of Europe's future low-carbon energy system, and in line with the emissions reductions required across the whole economy by 2050.

Recommendation 2: Policies and incentives that drive investment

› *Incentivise CCS through "carrots" and "sticks" applied to fossil fuel producers*

A renewed sense of direction for CCS requires the means to make it happen: CCS cannot be solely supported by the weak investment signal from the EU's Emissions Trading System (ETS). Targeted policy and financial incentives will engage industry and provide an enduring, credible and bankable business case for investment. Incentives must engage the oil and gas sector as the key delivery agents for CO_2 storage at commercial scale. A CCS certificate system could do this by requiring storage of increasing volumes of CO_2 over the coming decades. Combined with tax incentives, it could promote the rapid use of depleting oil and gas fields for CO_2 storage and develop large saline aquifer stores.

ENABLING ACTIONS

Recommendation 3: Sourcing low-cost CO_2

› *Accelerate CCS by sourcing high-purity CO_2 captured from industry*

The deployment of North Sea CO_2 storage depends on the timely investigation and proving of geological formations suitable for the task. Pre-commercial test injections of CO_2 are needed to achieve this. Industrial sources of high-purity CO_2 are available now at low cost and present an opportunity to carry out this practical and essential work. These efforts would result in the cost-effective establishment of storage assets, the de-risking of longer term, commercial-scale CCS operations, and better engagement with industrial sectors that will depend on CCS to reduce CO_2 emissions.

Recommendation 4: The transport link in the chain

› *Advance CCS by developing CO_2 infrastructure as Projects of Common Interest*

The EU's Connecting Europe Facility positively includes CO_2 infrastructure as a specific area of interest, but it lags far behind consideration of electricity and gas infrastructure investments. The European Commission should issue a specific call for CO_2 transport projects during 2014, including the development of CO_2 transport infrastructure hubs and the shipping of CO_2 from industrial sources as a means of supporting the characterisation of North Sea storage sites. These can be funded as collaborative Projects of Common Interest.

Recommendation 5: Establishing CO_2 storage for Europe

› *Validate North Sea storage capacity through six early projects*

The North Sea is Europe's primary CO_2 storage asset. It has immense storage potential and can secure public permission to operate. For the next five years, its surrounding nations must focus on delivering six pre-commercial operational CO_2 storage sites to validate a variety of CO_2 storage options and prove the availability of at least 1 to 2 gigatonnes of bankable storage capacity. This will satisfy storage needs for initial projects up to 2030. By 2025, Europe will need to validate 15 times this amount to create confidence for large-scale commercial investments in CCS, which will store CO_2 through to 2050 and beyond.

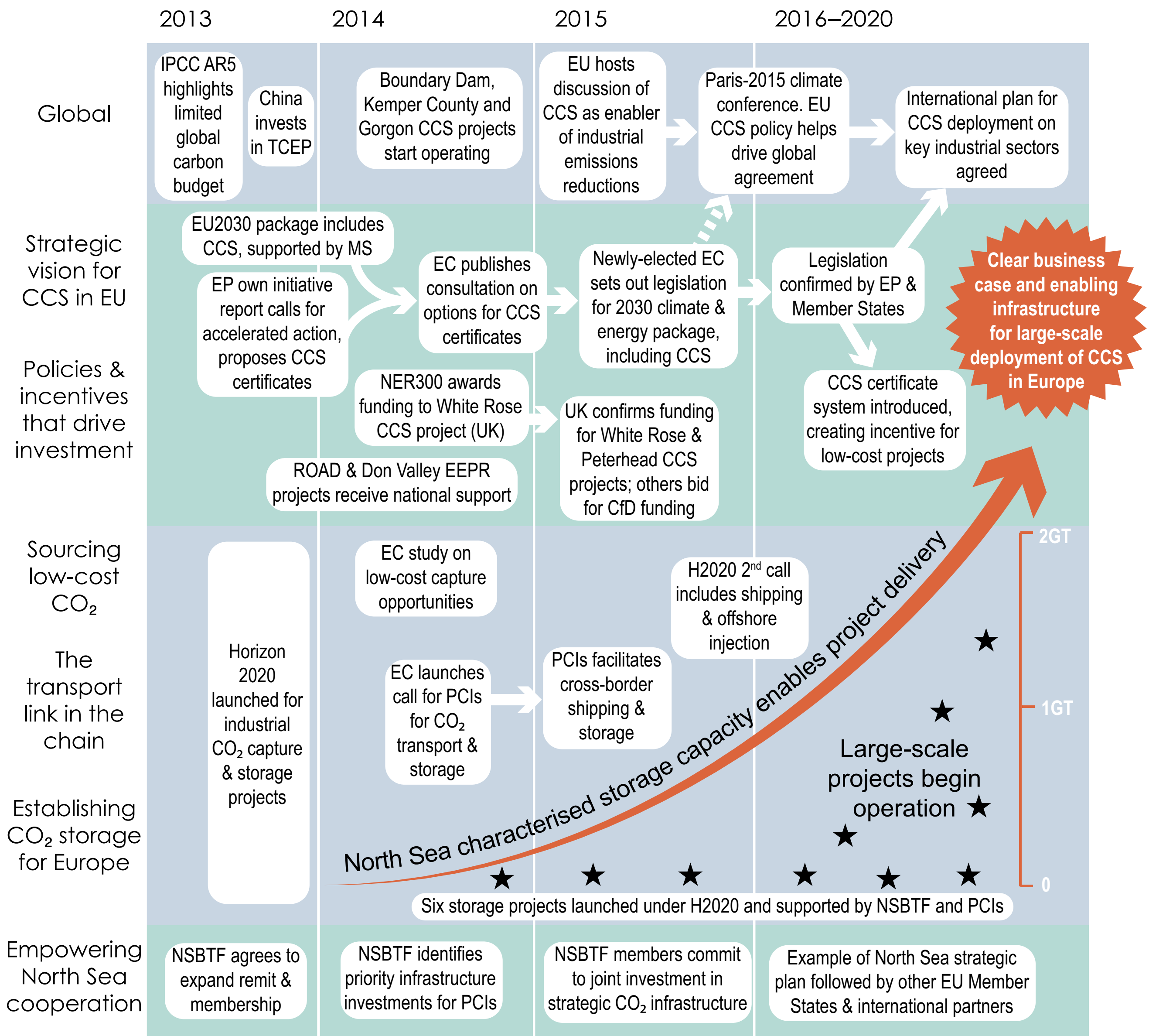
Recommendation 6: Empowering North Sea cooperation

› *Support CCS efforts by reinvigorating government and industry collaboration*

If Europe is to unlock North Sea CO_2 storage, it will require the proactive engagement of additional governments and a broader set of stakeholders. There is an urgent need to revitalise and empower the North Sea Basin Task Force (NSBTF) as a forum for strategic collaboration and challenge, driven by bottom-up innovation and practical implementation. It must bring together the practical actions identified here to step up the capture, transport and storage of CO_2, and provide the necessary collaborative political drive to secure Projects of Common Interest and a supportive EU policy framework.

A five-year framework

The recommendations presented in this report propose a pathway towards the large-scale deployment of CCS in Europe. Fresh efforts are required over the next five years to make this a reality, with practical actions and policy incentives combining to create a framework for investment. This timeline provides an overview of how these different measures – within the six areas identified in this report – combine to provide both a clear business case and the enabling infrastructures required. Europe's CCS policy forms part of global efforts to address climate change. We therefore also show how renewed efforts on CCS can form part of a broader international effort.



Key:

TCEP	*Texas Clean Energy Project*	*CfD*	*Contracts for Difference*
EC	*European Commission*	*NSBTF*	*North Sea Basin Task Force*
MS	*Member States*	*PCI*	*Projects of Common Interest*
EP	*European Parliament*	*EEPR*	*European Economic Programme for Recovery*

Why Europe needs a CO_2 storage solution

“If the world is to have a reasonable chance of limiting the global average temperature increase to 2°C … less than one-third of proven reserves of fossil fuels can be consumed prior to 2050, unless CCS technology is widely deployed.”
World Energy Outlook 2012, International Energy Agency (IEA)

“Abundant CO_2 storage capacity, clusters of CO_2 sources, world-class research institutes and commercial stakeholders … makes the North Sea countries natural leaders for the development and deployment of CCS technology in Europe.”
One North Sea: A study into North Sea cross-border CO_2 transport and storage, Element Energy

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“For all fossil fuels, [CCS] will have to be applied from around 2030 onwards in the power sector in order to reach the decarbonisation targets.”
European Commission Energy Roadmap 2050

“If CCS is removed from the list of emissions reduction options in the electricity sector [worldwide], the capital investment needed to meet the same emissions constraint is increased by 40%.”
Energy Technology Perspectives 2012, IEA

“Ensuring a European stake in the global CCS industry will also increase employment in green industries – creating and preserving thousands of jobs.”
CCS in EU energy-intensive industries, ZEP, 2013

“UK gas and coal power stations equipped with carbon capture, transport and storage have clear potential to be cost competitive with other forms of low-carbon power generation.” *UK CCS Cost Reduction Taskforce – Final Report*

“Successfully deploying [CCS] would be a huge economic prize for the UK in its low carbon transition, cutting the annual cost of meeting our carbon targets by up to 1% of GDP by 2050.”
CCS: Mobilising private sector finance for CCS in the UK, ETI and Ecofin

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“CCS is currently the only large-scale mitigation option available to make deep reductions in the emissions from industrial sectors such as cement, iron and steel, chemicals and refining.”
Tracking Clean Energy Progress 2013, OECD/IEA

“CCS is vital for meeting the [European] Union’s greenhouse gas reduction targets and it offers potential for a low-carbon re-industrialisation of Europe's declining industries.”
European Commission Communication on Future of CCS in Europe, 2013

“The fact is that any new fossil resources brought to market, conventional or unconventional, risk taking us further away from the trajectory we need to be on, unless there is a firm CCS requirement in place or governments are prepared to risk writing off large amounts of invested capital.”
Angel Gurría, OECD Secretary-General

Creating the Climate for CCS in Europe

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1 The North Sea – a game-changing asset

"The North Sea is the most important CO_2 storage region for the whole of Europe. We propose that it is both possible and necessary to commence carbon storage as soon as possible, to transfer capability from science to industry and build confidence for investors in the short and long term"

Prof Stuart Haszeldine, SCCS

The CCS challenge for Europe

CARBON dioxide emissions are the major cause of climate change: that is unequivocal. Limiting the effects requires restricting the total amount of fossil carbon that is combusted and emitted as CO_2. By 2044, the world will have burned enough carbon to initiate a 2°C global temperature rise. CCS is the only technology that directly reduces these emissions at source and explicitly enables the management of carbon budgets.

Over the past five years, Europe's efforts to implement CCS technology have failed to deliver. The next five years will be crucial in putting CCS back into position as an enabler of Europe's transition to a low-carbon economy. This is unavoidable, as there are no substitutes for CCS to reduce CO_2 emissions in many industrial sectors. In a world intent on addressing climate change, CCS is invaluable and indispensable as a means of retaining hundreds of thousands of industrial jobs and improving Europe's low-carbon competitiveness. Global progress on developing commercial CCS projects shows that CCS will work. But CCS will only be delivered if it is clearly supported by policy makers. In Europe, practical actions must be combined with durable policy drivers to rebuild confidence and attract investment.

Europe's strategy on CCS has been logical but is now flawed. It assumed that direct funding of demonstration projects on power plants would make the technology available for deployment, while a rising CO_2 price would provide a business case. In reality, the economic crisis and collapse of the carbon price means that neither part of this combination of technology push and market pull has delivered. Most importantly, it has failed to provide a business case for the provision of CO_2 storage, without which large-scale CCS deployment is impossible.

To break out of this dead end, Europe needs to find more accessible routes to CCS deployment. Instead of a narrow focus on the slow procurement of integrated large-scale power generation projects, Europe can more rapidly accelerate action on the enabling infrastructures of CO_2 transport and geological storage. Development of a diverse series of pre-commercial projects is a proven innovation method to aid the introduction of new technologies. By using low-cost available sources of CO_2, this approach will help reduce system costs and enable swifter progress toward emissions reduction targets.

The North Sea is the largest CO_2 storage resource in Europe, and offers the ideal location for immediate practical actions: it is ringed by major industrial regions that can supply CO_2; with a well-characterised and suitable geology it has a unique combination of large and diverse CO_2 storage opportunities with a total capacity sufficient for hundreds of years of emissions; its existing hydrocarbon industries have world-leading subsurface and offshore engineering experience, with existing infrastructures in place for oil and gas production; most importantly, supportive neighbouring countries and regions can provide the necessary regulations and public permission to operate.

In a carbon-constrained world, policy makers and industry alike will need to focus on the geological and geographical implications of energy investment. Progress in offshore renewables and electricity grids is being delivered through sustained partnership efforts by policy makers, industry and the research community. It is time for CCS to benefit from the same joined-up strategic action: practical efforts and policy incentives can unlock North Sea CO_2 storage for Europe.

Learning from elsewhere; building on Europe's strengths

EXPERIENCE from around the world already shows that CCS projects can be delivered. Australia, Canada, China and the USA are all seeing proactive investments in the development and construction of commercial-scale CCS projects. Crucially, these are in a diverse range of sectors: gas processing, refining, chemicals, biomass conversion and electricity generation. Collectively, these projects will soon be injecting many tens of millions of tonnes of CO_2 into secure geological storage – potentially, 38Mt a year by 2016[1]. In Europe, the predominant focus to date on complex and expensive electrical power generation projects ignores many cost-reduction opportunities and the "low-hanging fruit" of available pure CO_2 streams from industrial sources.

Europe's world-leading technology companies, engineering contractors and project developers all need a strong domestic market if Europe is to benefit from global CCS opportunities. But Europe now has to work differently to reposition CCS for deployment. One starting point will need to be delivery of the remaining power generation projects supported by existing funding programmes. In parallel, practical and proactive efforts can create the conditions for broader deployment of CCS through smaller scale strategic projects utilising industrial emissions of CO_2.

Europe can deploy and expand on its world-leading resources of scientists and technology companies with over a decade of experience in CCS research, development and delivery. The EU's Framework Programmes have a proven record of developing and applying research to deliver results. Its new Horizon 2020 programme will provide a valuable focal point for pan-EU CCS activity. The proposed initial emphasis on both CO_2 capture from industrial sources and proving of geological storage is welcome. It should further be used as a vehicle to coordinate the progression of CCS research into commercial projects. But this initiative alone will not be enough.

ACTIONS should focus on coalitions of the willing: countries around the North Sea region that will take practical steps to develop a shared European CO_2 storage resource

[1] *The Global Status of CCS: 2013*, GCCSI

Strategic infrastructure investments to accompany Horizon 2020 are also required to make the most of this opportunity, and catalyse low-cost, high-value CCS projects at pre-commercial scale. These projects must make visible what can be achieved, and provide a practical approach to building alignments between research, industry and decision makers. Such actions should focus on coalitions of the willing: countries around the North Sea region that will be the first to take practical steps to develop a shared European CO_2 storage resource.

Real opportunities exist in the short term to utilise existing sources of emitted CO_2 in order to characterise and confirm geological storage assets. Well before 2020, the transport of low-cost CO_2 from high-purity emission sources to identified storage sites can be achieved using CO_2 shipping and existing pipelines. This can validate timely and cost-effective CO_2 storage and develop associated CO_2 handling facilities. It will also initiate the creation of clusters of emitters around the North Sea, forming CO_2 transport hubs. This "bottom-up" approach can build on the success story of European CCS research and integrate lessons learned from elsewhere. The EU's Projects of Common Interest can support this effort and help the best-placed countries bordering the North Sea to jointly advance the first infrastructure projects. But without a clear strategic direction for pan-European efforts to reduce CO_2 emissions via CCS, large-scale and commercial investments will not be made by industry or by governments.

Now is the time: CCS in the 2030 framework

EUROPE'S faltering efforts to deliver commercial and demonstration-scale CCS projects have shown that, without a longer term business case, such projects will not progress. Member State governments, the EU and industry must now work together to create a robust and durable CCS policy.

In light of renewed scientific warnings about the risks of climate change, the need for CCS is more pressing than ever. The EU is currently considering its policy framework for climate action in the period to 2030 and beyond. This must provide a clear vision for CCS, with policy drivers and financial incentives that can catalyse sustained investment across all industry sectors. In late 2015, world leaders will meet in Paris to shape the next phase of global actions on climate change. Before then, Europe needs to have a clear strategy in place for how CCS will help it to drive reductions in CO_2 emissions from industry and power generation. Timelines for this framework must quantify ambitions for the amount of CO_2 captured and stored over the coming decades, to drive the construction of enabling infrastructures and provide a business case for industry investment in the development of CO_2 storage.

> *MEMBER State governments, the EU and industry must now work together to create a robust and durable CCS policy*

The deployment of CCS in Europe is being held back, not by technology, but by investor confidence, finance and politics. Europe has all the skills and technology it needs to make a success of CCS. The challenge now is to find the right package of practical actions, financial models and policy drivers to make it happen. **The following six recommendations set out immediate steps that will help unlock North Sea CO_2 storage for Europe.**

2 Recommendations

WE set out here six recommendations for European policy makers and stakeholders, identified and developed from discussions at the SCCS Conference 2013, *Unlocking North Sea CO_2 Storage for Europe*. They describe how fresh policies and actions to enable projects to evolve from research to development can combine in the coming five years to enable rapid CCS deployment by 2020.

These sets of actions focus on the key challenges facing the deployment of CCS in Europe, providing a new agenda that increases Europe's chances of success. We start with the policy context and drivers for investment before considering practical opportunities for each of the areas of CO_2 capture, transport and storage. The delivery of each will depend on improved cooperation between governments and other stakeholders.

THE POLICY CONTEXT

Recommendation 1: A strategic vision for CCS in 2030

› Position CCS for deployment sufficient for EU industrial emissions and power generation

CCS needs to be explicitly addressed in the European Union's 2030 framework for climate and energy policy, stating the scale of CCS deployment intended and, consequentially, the timescales for investments in the enabling infrastructures needed for CO_2 storage and transportation. The 2030 framework should place CCS strongly alongside actions to support renewable power generation and energy efficiency as part of Europe's future low-carbon energy system, and in line with the emissions reductions required across the whole economy by 2050.

CCS is not optional to achieving climate mitigation; it is essential. To deliver decarbonisation of the European economy, CCS will need to be widely deployed by 2030, and be the default option for new investment in fossil-fuelled power generation and high-emitting industrial facilities. Transport and storage infrastructures will also need to be in place at sufficient scale to enable further emissions reductions out to 2050. European technology companies and project developers are capable of delivery but need clarity, coherence and support on the ambition and timetable to regain lost momentum and catch up with CCS progress in North America and China.

In support of the 2030 framework, the European Commission should set out how CCS will contribute to job retention and the sustained low-carbon competitiveness of European industry in a carbon-constrained world. This refreshed strategy will need to pull together practical actions already in place, such as Horizon 2020 and Projects of Common Interest, together with the small number of continuing CCS demonstration projects on power generation. CCS investments will inevitably be focused initially on those locations best able to access CO_2 storage, and it is in the interest of all EU Member States that they succeed. However, all EU Member States should be required to set out quantified assessments of how CCS (or alternatives) will be deployed by the power sector and industrial emitters over the coming decades in order to deliver emissions reductions and keep pace with, or exceed, emissions reduction in other regions worldwide.

Recommendation 2: Policies and incentives that drive investment

› Incentivise CCS through "carrots" and "sticks" applied to fossil fuel producers

A renewed sense of direction for CCS requires the means to make it happen: CCS cannot be solely supported by the weak investment signal from the EU's Emissions Trading System. Targeted policy and financial incentives will engage industry and provide an enduring, credible and bankable business case for investment. Incentives must engage the oil and gas sector as the key delivery agents for CO_2 storage at commercial scale. A CCS certificate system could do this by requiring storage of increasing volumes of CO_2 over the coming decades. Combined with tax incentives, it could promote the rapid use of depleting oil and gas fields for CO_2 storage, and develop large saline aquifer stores.

Experience beyond the EU shows that CCS projects can be delivered where a business case exists. However, Europe has failed to provide a value proposition for CCS. To secure investment, it must look at ways of providing revenues for CCS projects, rather than relying on the uncertain investment signal of future carbon prices. There is a particular need to engage the hydrocarbon sector, which has the skills, experience and infrastructure required to accelerate action. The sector is responsible for significant volumes of emissions, and also has crucial operational knowledge of assessing geological risks, as well as the ability to manage rapid construction.

Existing CCS projects in Norway, the USA, Canada and Australia show that the oil and gas sector can deliver CCS, either when required as part of its licence to operate or when incentivised by financial returns. At present, within the EU, there is no business case for the hydrocarbon industry to invest in CCS and CO_2 storage. This central flaw can be addressed by a two-fold approach as part of the EU's 2030 framework:

- The EU can shift the locus of regulation upstream, onto producers and importers of fossil fuels, to require progressively increasing responsibility for storing the resulting CO_2 emissions. Of the options under consideration, a **CCS certificate system** would be the most viable mechanism as it can be adjusted over time to reflect the tightening of carbon budgets to avoid dangerous climate change.

- Member States can encourage the use of **CO_2 for enhanced recovery of oil and gas** from existing fields – thereby incentivising CO_2 storage, addressing energy security concerns, fast-tracking the availability of essential infrastructure and providing tax revenues to offset early public-sector investment in CCS.

Time is of the essence. There is a diminishing window of opportunity before North Sea oil and gas field closures and infrastructure decommissioning put many opportunities for investment beyond reach. If devised as part of the low-carbon transition, tax incentives for enhanced hydrocarbon recovery that privilege the use of CO_2 over other competing options would create immediate motivation for operators to develop plans for the remaining life of existing fields. This would accelerate the confirmation of North Sea offshore storage potential, begin the development of long-term storage clusters and maximise the CO_2 storage resource.

Carrot and stick: the motivation for CCS

By addressing CO_2 capture and storage directly, CCS certificates can provide revenues for industrial CCS projects and rapidly pull in lower cost sources of CO_2. Importantly, if targeted at fossil fuel producers, certificates would directly engage key sectors that need to improve efforts on decarbonisation and avoid the risk of stranded assets.

Unlike the current ETS model, which adds costs to **consumers** of fossil fuels, an upstream CO_2 certificate would require **producers** (and importers) to act to ensure that CO_2 is stored. Those companies would contribute on the basis of the carbon intensity of their product, providing a revenue stream for the most productive and cost-effective CCS projects. The increasing demand for storage capacity would then provide a trajectory for a North Sea transition from purely hydrocarbon production to including CO_2 storage. Rather than trying to pre-determine the number of capture projects onshore, or rely on an uncertain price for emissions, the central driver for the scaling-up of CCS will be confidence in the desired growth in the storage of CO_2 over the coming decades.

Tax incentives, as shown in the USA, can help to develop CO_2 storage and CO_2-enhanced oil recovery (CO_2-EOR). Some European governments are seeking to enable shale gas developments or continue conventional coal, lignite or oil and gas production through new tax allowances. Without CCS, this is unsustainable. Instead, incentives that embed CO_2 storage in the business model will enable hydrocarbons extraction in a manner consistent with climate policy objectives.

The Sleipner gas extraction platform in the North Sea where Norway's Statoil has been capturing and storing CO_2 since 1996
Photo: © Dag Myrestrand / Statoil

ENABLING ACTIONS

Recommendation 3: Sourcing low-cost CO_2

› **Accelerate CCS by sourcing high-purity CO_2 captured from industry**

The deployment of North Sea CO_2 storage depends on the timely investigation and proving of geological formations suitable for the task. Pre-commercial test injections of CO_2 are needed to achieve this. Industrial sources of high-purity CO_2 are available now at low cost and present an opportunity to carry out this practical and essential work. These efforts would result in the cost-effective establishment of CO_2 storage assets, the de-risking of longer term, commercial-scale CCS operations, and improved engagement with industrial sectors that will depend in future on CCS to reduce CO_2 emissions.

The long-term success of CCS depends on the delivery of suitable and sufficient CO_2 storage capacity. The establishment of bankable CO_2 storage assets, sufficient for an entire project lifespan, is required before there is commercial sanction to proceed with any CCS project. If no legacy data exist from hydrocarbon production, saline aquifer storage will require several years of research and operational testing. At present, the proving of potential storage assets is held back, in part, by a lack of available CO_2. However, millions of tonnes of high-purity CO_2 from industrial facilities, such as ammonia plants and gas processing facilities, are simply emitted to the atmosphere every year.

Europe can bring preparations for CCS deployment back on track by using industrial CO_2 resources, as the North American regional sequestration partnerships have already proven[1]. The use of existing high-purity CO_2 sources in early CCS projects will enable rapid "learning by doing", leading to transport and storage solutions five years faster than waiting for large-scale power generation projects with CO_2 capture to be built. This proactive move will enable Europe to extend its strategic vision, and feed innovative technology solutions to the industrial sectors.

The first call of the EU's Horizon 2020 programme in late 2013 is expected to include CO_2 capture from industrial sources and biomass, and this will provide a valuable focus for further research. But it must be accompanied by the identification of potential CO_2 sources in proximity to the North Sea. The European Commission should rapidly undertake a study to identify low-cost, high-value CO_2 sources and their availability for storage site characterisation efforts. During the next five years, Member States can integrate these opportunities into their strategies for decarbonisation and geological storage site characterisation and testing. With such clear benefits, these projects should be eligible for support as part of Projects of Common Interest, and supported through any future low-carbon innovation funding mechanisms.

THE European Commission should rapidly undertake a study to identify low-cost, high-value CO_2 sources and their availability for use in storage characterisation efforts

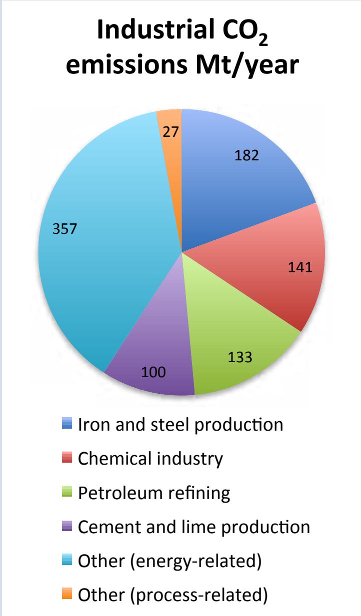
[1] *NETL: Regional Carbon Sequestration Partnerships*, www.netl.doe.gov/technologies/carbon_seq/infrastructure/rcsp.html

Industrial strengths

Large volumes of high-purity CO_2 are already being produced by operations across Europe, such as natural gas processing and hydrogen production for ammonia manufacture. Some of these are located where commercial CO_2 capture options are already in use.

Ammonia plants across the whole of Europe are already separating around 6-7 million tonnes a year of high-purity CO_2, which is available now. Many of these sites are located on coasts or large rivers. Facilities located within 200km of North Sea coastlines could immediately provide around 3Mt a year. Other sectors, such as methanol and ethanol production, could also provide quick-win supplies of low-cost CO_2. As carbon feedstock was shipped or piped in, it is feasible to reverse the process. Using this CO_2 in storage characterisation will transform the industrial site into a pioneering low-carbon producer.

Europe can capitalise on these opportunities and use these sources to kickstart early storage projects, establish bankable storage assets, de-risk CCS deployment and encourage investment.



Member States' CO_2 emissions by sector in 2010. Source: ZEP, 2013

Recommendation 4: The transport link in the chain

› Advance CCS by developing CO_2 infrastructure as Projects of Common Interest

The EU's Connecting Europe Facility positively includes CO_2 infrastructure as a specific area of interest, but it lags far behind consideration of electricity and gas infrastructure investments. The European Commission should issue a specific call for CO_2 transport projects during 2014, including the development of CO_2 transport infrastructure hubs and the shipping of CO_2 from industrial sources as a means of supporting the characterisation of North Sea storage sites. These can be funded as collaborative Projects of Common Interest.

During the next five years, there will be opportunities to reuse existing North Sea oil and gas sector pipeline infrastructure, which should be actively encouraged. This is of particular relevance to the potential development of CO_2-EOR as a form of storage in the North Sea, where decommissioning of oil and gas infrastructure sets a deadline to incentivise its re-use. To identify early opportunities for CO_2 capture, the EC and Member States should work together to identify a "no regrets" set of infrastructure investments as a key enabler of CCS ahead of commercial-scale projects coming on line. These can be funded as collaborative Projects of Common Interest.

> *"Opportunities for the integration of CO_2 transport networks across national borders, particularly in … OECD Europe, will need to be explored thoroughly and as early as possible"*
>
> *IEA, 2013*

Further innovation in CO_2 transport will also support the development of early storage projects. Tens of thousands of tonnes a year of liquefied CO_2 are already transported by ship for use in the food and chemicals sectors. Shipping can provide a means of supporting the capture of available pure CO_2 streams from industrial processes, transporting it to hubs or directly to injection sites for use in the characterisation of CO_2 storage options. In future calls, Horizon 2020 will be able to consider innovative transport solutions: for example, offshore injection linked to the transport of CO_2 by ship.

The cross-border movement of CO_2 is permitted for food or chemicals production, or for use in EOR. However, legal barriers impede its transportation for geological storage. A series of bilateral agreements on permitting processes and liabilities will therefore be essential in the short term. This is directly relevant to Member States with insufficient or unavailable storage capacity to meet their own CCS ambitions. A replicable format for bilateral negotiations between Member States and transit or storage jurisdictions will help to address this – seeking to establish a permitting timescale for cross-border CO_2 transport and trans-boundary CO_2 storage projects, and enabling the informed planning of pan-EU CCS deployment. For initial storage validation projects, the liability for CO_2 will lie with receiving Member States, or be underwritten by a European bond. After validation, the risk will decline, allowing countries to take on liability more easily.

Recommendation 5: Establishing CO_2 storage for Europe

› Validate North Sea storage capacity through six early projects

The North Sea is Europe's primary CO_2 storage asset. It has immense storage potential and can secure public permission to operate. For the next five years, its surrounding nations must focus on securing six pre-commercial operational CO_2 storage sites to validate a variety of CO_2 storage options and prove the availability of at least 1 to 2 gigatonnes of bankable storage capacity. This will satisfy storage needs for initial projects up to 2030. By 2025, Europe will then need to validate 15 times this amount to create confidence for large-scale commercial investments in CCS, which will store CO_2 to 2050 and beyond.

Europe should aim for at least six dedicated, pre-commercial storage projects before 2020, including CO_2-EOR, as recommended by ZEP. These projects will develop a range of storage options from different Member States, convert storage resource estimates into proven reserves, and bring forward the availability of the most plausible storage formations. A structured and collaborative approach of such ambition will provide the foundation for future CCS deployment.

Knowledge sharing – mainly of information derived from oil and gas field data currently held in confidence – would support the pre-characterisation of feasible storage sites, with national and EU programmes mediating such access. The viability of all six pre-characterised storage sites could also be tested more rapidly using currently available industrial CO_2 streams (see *Recommendation 3*). The first call of Horizon 2020 will support CO_2 storage research but, to secure the availability of CO_2 storage at scale, this must be backed by Member State and industry investment in order to deliver pre-commercial projects. Initial efforts can usefully focus on depleted oil and gas reservoirs with surrounding saline aquifers, which should seek to complement field lifecycles and allow existing infrastructure to be put to good use.

Project activity should also inform regulation and public opinion. The development of operational storage data and monitoring methods can be fed back to regulators. It can also be used to engage with stakeholders and communities, and clarify legal arrangements for CO_2 storage, which currently limit test injections to 100,000 tonnes of CO_2. The fact that many suitable geological storage strata extend across national boundaries, as with hydrocarbon fields, should not be a restriction on realising their potential. To enable the matching of available CO_2 with suitable offshore storage, regulators should extend bilateral arrangements on cross-boundary CO_2 transport (see *Recommendation 4*).

Overall, a “bottom-up” approach to projects should be fostered, with the research community, industry and governments working in partnership to deliver these critical developments. The successful delivery of CO_2 storage will inform and reduce technical, financial and social risks associated with CCS. This model can subsequently be expanded into the Baltic and Irish seas to support these Member States in identifying and proving CO_2 storage assets.

Benefits of CO_2-Enhanced Oil Recovery

Injecting CO_2 into partly depleted oil or gas fields can produce 10-20% more hydrocarbons, a process used successfully in North America for decades. It seems paradoxical, yet the carbon footprint of this method may be less than developing new resources, such as shale oil (*Figure 1*).

The benefits of CO_2-EOR include the construction of infrastructure and proving of CO_2 storage sites at no direct cost to EU taxpayers; billions of euros in tax revenues to fund capture projects and transport systems (especially offshore); and CO_2 injection into hydrocarbon fields acting as efficient storage sites.

Carbon balance can be regained by continuing to inject CO_2 for storage after hydrocarbon production has ceased. Initial research by the University of Edinburgh suggests CO_2 would need to be injected purely for storage for the same period of time as the EOR operation. Europe’s limited number of commercial CO_2-EOR opportunities will restrict oil recovery to a 10-20 year transition to CCS.

CO_2-enhanced gas recovery is still in its infancy but, with greater availability of CO_2, it may well be used at North Sea gas fields. If CO_2 is stripped during production, it could be stored in depleted fields or saline aquifers, as already occurs at the Sleipner and Snøhvit CCS projects in the Norwegian North Sea.

The carbon intensity of oil production (adapted from Mangmeechai, 2009)

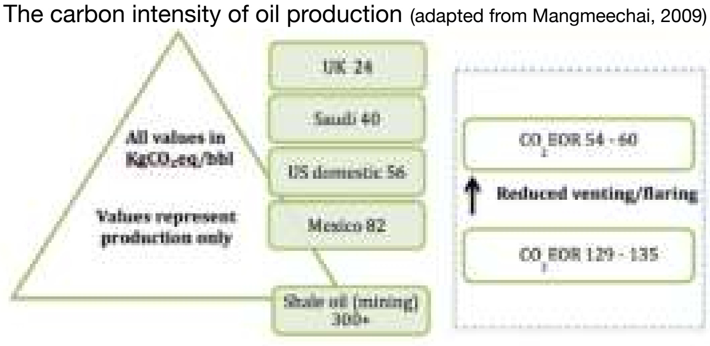


Figure 1: *Initial results from University of Edinburgh research (right-hand boxes) suggest that the carbon footprint of best-practice CO_2-EOR, with e.g. reduced gas flaring/venting, is similar to USA domestic oil production and significantly lower than shale oil production. CO_2-EOR will enable continued production of low-carbon intensity base oil that might cease if EOR is not undertaken. (NB Values represent production emissions only. Figures represent emissions only associated with incremental oil. Units in kg of CO_2 equivalent per barrel.)*

Recommendation 6: Empowering North Sea cooperation

› **Support CCS efforts by reinvigorating government and industry collaboration**

If Europe is to unlock North Sea CO_2 storage, it will require the proactive engagement of additional governments and a broader set of stakeholders. There is an urgent need to revitalise and empower the North Sea Basin Task Force (NSBTF) as a forum for strategic collaboration and challenge, driven by bottom-up innovation and practical implementation. It must bring together the practical actions identified here to step up the capture, transport and storage of CO_2, and provide the necessary collaborative political drive to secure Projects of Common Interest and a supportive EU policy framework.

Current forms of collaboration between governments and stakeholders on North Sea CCS opportunities are weak. The NSBTF began as a joint initiative between the UK and Norway in 2005 to develop common principles to regulate CCS, and its membership was subsequently widened to include Germany and The Netherlands. But the forum was not intended to help deliver practical projects and has been overtaken by efforts in other sectors that focus on electricity infrastructure and offshore renewable power generation. In combination, the Northern European Energy Dialogue, the North Seas Countries' Offshore Grid Initiative and Norstec provide a focus for political leadership, policy and regulatory coordination, and industry cooperation.

A renewed NSBTF can follow these examples and make a priority of assisting cooperation between industrial emitters, the providers of CO_2 transport and storage solutions, regional governments, public authorities, regulators and researchers. These stakeholders must be empowered to identify and deliver strategic CCS investments, and define an agenda that demands proactive government efforts to scale up and speed up CCS investment.

In order to roll out CCS commercially across the EU from 2020, all stakeholders will need to work together to develop Projects of Common Interest for CO_2 transport and storage in the North Sea. These efforts will be rewarded: regulatory frameworks and engineering solutions for trans-boundary CO_2 transport and storage will be designed and tested as a result. This will substantially de-risk future commercial investments, and provide solutions to legal constraints on cross-boundary storage. It will also provide storage solutions for Member States with a need for commercial CO_2 capture but a lack of onshore CO_2 storage assets.

The Case for North Sea CO_2 Storage

The following chapters capture the essence of talks and debate from the SCCS Conference 2013, which have guided the recommendations defined in the preceding section.

3: Where next for CCS in Europe? 22

4: Global progress: lessons for Europe 24

5: Sourcing CO_2 to accelerate storage 27

6: The link in the CCS chain 30

7: Tapping into North Sea CO_2 storage 33

3 Where next for CCS in Europe?

EUROPE has tried to support the demonstration of CCS over recent years. In 2007, the European Union recognised the need to keep global warming below 2°C to limit the worst impacts of climate change. Two years later, the CCS Directive laid down a legal framework for the geological storage of CO_2. Despite this, the continuing gap between policy foundations and the real-world investment challenge suggests that its approach needs a fundamental re-set. Meanwhile, scientific concern over the causes and impacts of climate change continues to grow, and it is increasingly recognised that CCS can play a major role in reducing the costs of decarbonisation – particularly for industrial sectors, which lack alternatives to the use of fossil fuels. Despite this, the gap between the need for CCS and the prospects for its delivery has been widening.

"It is clear that Europe does not currently have a CCS policy"

Chris Davies MEP

Speaking at the SCCS conference, Chris Davies MEP and Dr Graeme Sweeney, Chairman of ZEP, both highlighted how the original incentive framework of carbon pricing and support for demonstration projects, through the EU's ETS, has failed to deliver either a long-term business case or sufficient initial funding for CCS. To move forward, they pointed out, Europe will need to be more explicit about the outcomes it wishes to secure. The experience gained from successfully supporting renewables technologies shows that CCS policy must be clear about three things: 1) how much CCS is required; 2) how it will be paid for; and 3) for power generation projects, will it be able to function in economic terms within the electricity market.

These questions can only be answered by improving the overall incentive framework for CCS – which, in turn, requires a clearer vision of its role within a low-carbon economy. The EU's 2020 package achieved this for renewables by setting an overall level of ambition, and Member States then introduced support measures to secure investment. Looking ahead to the 2030 timeframe, progress could be made on CCS if it is considered in a similar goal-oriented way alongside other policy objectives for emissions reduction, renewables and energy efficiency.

"Delaying deployment by just 10 years would increase the cost of decarbonising the power sector by $1 trillion"

Dr Graeme Sweeney, ZEP

Positively, conference delegates were told, efforts are underway to identify and develop fresh policy approaches for CCS. The EC's Consultative Communication on the Future of CCS in Europe set out a number of policy options, including CCS certificates and emissions performance standards. The European Parliament is now, in turn, producing its own report on the implementation of CCS to date, together with proposals for a way forward. In combination, these EU-level processes can help set the agenda for CCS for the coming five years. This period will also see the review of the CCS Directive, which will need to revisit aspects of the current legal framework perceived as barriers to investment – for example, provisions on liability and cross-border transport for CO_2 disposal.

Beyond the need for clarity on Europe's overall ambitions for CCS, practical efforts are also required to address specific challenges facing the integration of the capture, transportation and storage of CO_2 at commercial scale. The USA has around 30 years of experience in operating CO_2 transport pipelines and injection sites. By contrast, Europe does not already have in place the enabling infrastructure for CO_2 transport and storage – which would reduce investment risks and support the development of economies of scale through clusters of emitters and storage options. What Europe does have, however, is a continuing commitment to research and development spending, and the desire to support the development of CO_2 infrastructure.

Conditions for Successful CCS

Condition	OK?	Comments:
1) Legislative Framework	Yes (?)	Storage is enabled by the CCS Directive (2009/31/EC)
2) Successful Demonstration	-	20 demonstration-scale projects running, but none in the EU (none from EEPR or NER300 yet)
3) Commercial Viability	No	ETS price too low
4) Public Acceptance	-	Challenges particularly with onshore storage
5) Infrastructure	Yes	Guidelines for Trans European Infrastructure
6) Innovation	Yes	Horizon 2020, The European Industrial Initiative on CCS (the SET plan)

The success of CCS in Europe will depend on various factors, including support for innovation and a sound commercial case, as Michael Schütz of the European Commission outlined in his address, The view from Europe: enabling CCS. *Graphic: Michael Schütz*

For the rest of this decade, the EU's Horizon 2020 and the Connecting Europe Facility can, respectively, assist Member States, industry and academia in bringing forward cooperative projects to help accelerate investment in CCS.

However, these initiatives will only be able to play a catalytic role if individual governments play their part in pursuing CCS. At the SCCS conference, Fergus Ewing MSP, Minister for Energy in the Scottish Government, reaffirmed Scotland's commitment to CCS as part of its climate objectives, energy and industrial policy. And he stressed the need for industry, government and academia to work in partnership in order to transform the "innovation and invention" already underway into a CCS industry.

Conference delegates later explored actions that would both tackle the challenges and capitalise on the opportunities highlighted by the keynote speakers.

Fergus Ewing, Minister for Energy, Scottish Government

4 Global progress: lessons for Europe

IT is increasingly recognised worldwide that CCS is a critical technology for delivering cost-effective decarbonisation. Most major economies are active in CCS, with varying degrees of maturity in their activity and ambition. European action on CCS sits within the context of these wider global efforts to demonstrate and deliver CCS, and Member States can learn from progress delivered elsewhere.

The SCCS conference heard from three speakers on projects and activity outside the EU. Eric Redman of Summit Power gave a detailed description of their leading Texas Clean Energy Project (TCEP), Prof Peter Cook of the research organisation CO2CRC presented research and project activity in Australia, and Dr Simon Bennett of the IEA discussed findings from the agency's 2013 review of its CCS roadmap and the seven key actions identified as a result (see panel *IEA's global roadmap for CCS*).

The IEA analysed the role of CCS in delivering minimum-cost decarbonisation globally and in major world regions, including OECD Europe. The technology is calculated to deliver 14% of cumulative global emissions reductions consistent with achieving a "no more than two degrees warming" objective, known as the 2D Scenario (2DS). And CCS is not confined to the power sector in this analysis – 45% of the CO_2 captured between 2015 and 2050 must come from industrial facilities. For OECD Europe, the IEA suggests that, by 2030, a total of 310 million tonnes of CO_2 each year should be captured, with roughly equal amounts coming from power sector and industry sources. By 2050, they anticipate OECD Europe having a greater proportion of CCS in industry than in power generation (*Figure 2, page 25*).

Despite their limited number worldwide, the CCS initiatives currently under way positively illustrate the diverse range of options for creating viable projects, showing how the business model for CCS in different sectors varies, and emphasising the importance of the interplay between commercial "carrot" and regulatory "stick" incentives (*Figure 3, page 25*). The details of the Gorgon gas processing project in Australia and the Texas Clean Energy Project in the USA, presented at the conference (see *page 26*), highlight the contrast between: 1) the relative simplicity of delivering CCS through regulation in the high investment return/high-purity CO_2 context of gas processing; and 2) the complexity of the business model required to secure investment in a CCS power project. The conference discussed how CO_2 captured by mature commercial technologies from gas processing, hydrogen and ammonia production had, as

IEA's global roadmap for CCS:

- Introduce financial support mechanisms for demonstration and early deployment of CCS to drive private financing
- Implement policies that encourage storage exploration, characterisation and development
- Develop national laws and regulations as well as provisions for multilateral finance that require new-build, base-load fossil-fuel power generation capacity to be CCS-ready
- Prove capture systems at pilot scale in industrial applications where CO_2 capture has not yet been demonstrated
- Increase efforts to improve understanding of CCS among the public and stakeholders and the importance of its deployment
- Reduce the cost of electricity from power plants equipped with capture through continued technology development and use of highest possible efficiency power generation cycles
- Encourage efficient development of CO_2 transport infrastructure by anticipating locations of future demand centres and future volumes of CO_2

"low-hanging fruit", helped develop CO_2 transport and storage infrastructure and knowledge in the USA and Canada, which could subsequently be utilised and built upon by CCS power and industry projects.

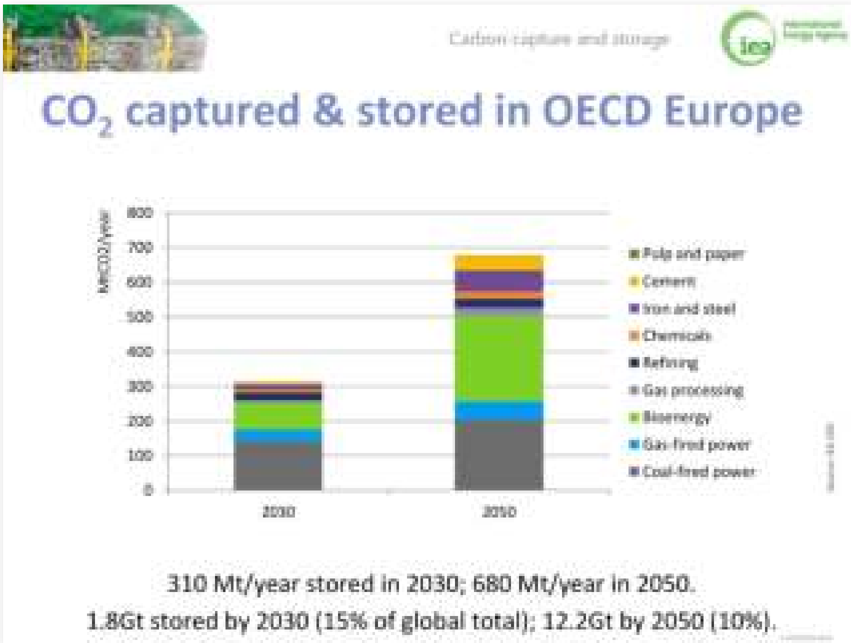


Figure 2: *The IEA's analysis of the volumes of CO_2 that must be captured and stored in OECD Europe by each sector, in its 2D scenario, as presented by Dr Simon Bennett at the SCCS conference*

Figure 3: *Prof Stuart Haszeldine provided conference delegates with a comparison of drivers behind some of the live projects developed outside the EU*

Gorgon CCS Project, Australia

The Gorgon project at Barrow Island, Western Australia, is a joint venture between three hydrocarbon majors – Chevron, Shell and ExxonMobil – to develop the offshore Greater Gorgon natural gas fields for liquefied natural gas (LNG) export. **The project demonstrates powerfully that, for gas processing, CCS is a commercially viable proposition that can be integrated into the natural gas production business**.

Gorgon's gas has a CO_2 content of around 14%, which must be removed to allow liquefaction, transport, sale and use. The CO_2 scrubbing technology has been in commercial use for many decades. The project has an estimated capital expenditure of around Aus$55 billion, of which just Aus$2bn (4%) relates to CO_2 storage. All funding comes from investors, with no government stake.

Barrow Island is a nature reserve, and the Western Australian goverment only granted permission for the development of the gas fields on the basis that the scrubbed CO_2 would be captured and stored. Subsequent measures were agreed between the developers and state and national government around CO_2 injection, storage and monitoring, and post-closure liability.

"If you can source CO_2 emissions from a gas [processing] plant, you gain five years over building a new power station"

Prof Peter Cook, CO2CRC

Texas Clean Energy Project, USA

The Texas Clean Energy Project (TCEP) was conceived by Summit Power to deliver CCS on a 400MW Integrated Gasification Combined Cycle (IGCC) coal power plant. **The project shows that a commercially viable CCS project on a power plant can be developed with the appropriate support and incentives**. It provides a robust technical and investment model that could be replicated in the EU, if sufficient incentives are secured.

TCEP received a US Department of Energy capital grant of US$450 million as well as investment tax credits. These, combined with secured off-take agreements for electricity, urea and CO_2 for EOR operations, and the use of commercially proven technology, have allowed Summit Power to present a robust business case and secure Chinese partners. A final investment decision is due in late 2013.

Summit Power has extensively engaged with and secured the support of the environmental community. A recognition that CO_2-EOR currently presents the most commercially viable and proven carbon sink led to a swift permitting process. Summit Power is seeking to develop a follow-on project in Scotland based on revenues from the UK's proposed Contracts for Difference (CfD) for low-carbon electricity production.

Construction works for the Gorgon project, Barrow Island, Western Australia. Photo: Jumbo, www.jumbomaritime.nl

5 Sourcing CO_2 to accelerate storage

EUROPE'S industrial sector contributes significantly to gross domestic product (GDP), jobs and innovation but it also encompasses emissions-intensive industries. In addition to energy usage, many production processes are inherent sources of CO_2, which means CCS is the only realistic option for achieving deep cuts in emissions (see panel *Industry's need for CCS*).

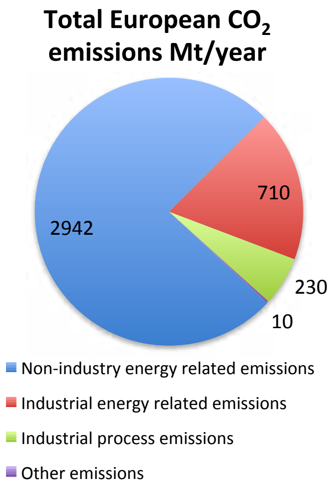


Figure 4: *Member States' CO_2 emissions in 2010, excluding land use, land-use change and forestry. Source: ZEP, 2013*

A recent SCCS briefing[1] provided conference delegates with an emissions profile for the industrial sector as well as the opportunities that this may present. The EU's total CO_2 emissions from all sectors in 2011 was 3,892Mt, with one quarter of this being emitted by industry[2] (*Figure 4*). These energy-intensive industries support thousands of jobs across the EU and represent considerable investment – for example, the iron and steel sector has an annual turnover of €74bn and directly employs more than 400,000 people, while Europe's refineries have a combined workforce of 100,000 in direct employment and an annual turnover of €497bn[1]. This would all be safeguarded through the deployment of CCS, as opposed to being threatened by carbon policies that did not include the technology.

Industry's need for CCS

- Direct CO_2 emissions from industry make up one quarter of total EU emissions
- 60% of the EU's industrial emissions come from four key sectors: iron and steel; chemical industry; petroleum refining; and cement and lime production
- 25% of EU emissions are inherent to the process chemistry of key materials: steel (blast furnace, reduction of iron ore); cement (calcination, lime from limestone); and hydrogen (steam reforming, for fuel upgrading, methanol and ammonia/ fertiliser production)
- Iron and steel, cement, refineries and chemicals combined have a turnover of €900 billion – around 7% of the EU's GDP, and representing 25% of EU industry
- These sectors directly employ a workforce of 1.75 million, 0.7% of the EU's labour force and 2.9% of EU industry employment

Source: [1]

The EC's roadmap for a 2050 low-carbon economy[3] sets targets for industry to reduce its CO_2 emissions by 34-40% (320-376Mt) compared to 1990 levels by 2030, and 83-87% by 2050. With CCS in the mix, a range of high-emission processes – including iron and steel, cement, hydrogen production and refining processes – could achieve combined reductions of around 200-300Mt of CO_2 each year – a significant contribution to overall reductions targets, which would not be achievable without CCS.

The development of a North Sea CO_2 storage hub and transport infrastructure network is essential if emissions are to be reduced from industry and other sectors. Recent 2050 decarbonisation roadmap studies by industry associations, including cement, steel, chemicals and pulp and paper producers, all point to

[1] *SCCS Briefing: CCS for Industrial Sources of CO_2 in Europe*, P Brownsort, 2013
[2] *CCS in Energy Intensive Industries*, ZEP, 2013
[3] *A Roadmap for moving to a competitive low carbon economy in 2050*, European Commission Communication, 2011

the need for CO_2 infrastructure and storage to be in place to enable these reductions. Many of these sectors will depend on further work to improve CO_2 capture technologies and reduce costs. But opportunities already exist to encourage investment in the first, and subsequent, CCS projects using commercially available technologies and pure CO_2 streams from industry (*Figure 5*).

The SCCS briefing provided an insight into these sources of high-purity CO_2 from industrial operations around the North Sea basin, which could feed early CCS projects and kickstart industrial CCS (*Figure 6*). These industrial emitters occur in clusters in different areas of Europe, with those in the north-west conveniently close to identified North Sea storage sites (see *Chapter 7: Tapping into North Sea CO_2 storage, page 33*).

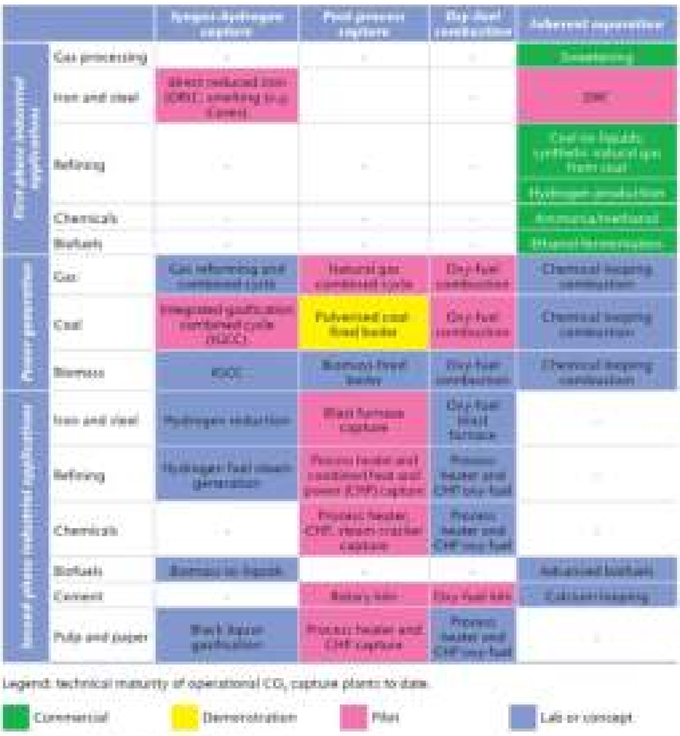


Figure 5: *Routes to CO_2 capture in power generations (by fuel) and industrial applications (by sector). Source:* Technology Roadmap: carbon capture and storage, *IEA, 2013.*

Numerous gas processing operations around the North Sea provide another source of pure CO_2 (currently being vented into the atmosphere) where naturally associated CO_2 must be stripped out to provide marketable natural gas. If tapped, these operations could provide millions of tonnes of high-purity CO_2 each year; for example, the Centrica facility in Morecambe Bay could yield 5Mt over 20 years.

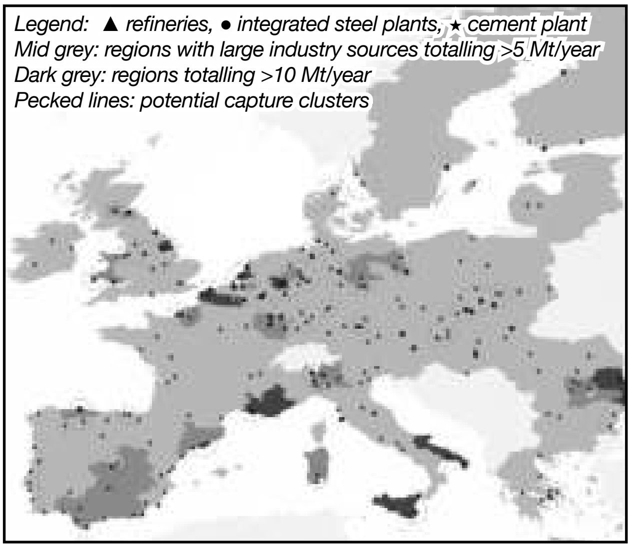


Figure 6: *The distribution in Europe of refineries, integrated steel plants and cement plants emitting more than 0.5Mt/year of CO_2. Source: P Brownsort, 2013, adapted from Rootzén, et al,* Prospects for CO_2 capture in European industry*, Management of Environmental Quality, 22, (1), 2011*

Identified options for CCS at large industrial sources could contribute most of the CO_2 emissions reductions needed by 2030. As discussed by conference delegates, it is now necessary for the EU and individual Member States to provide appropriate policies and support mechanisms that will achieve the rate of deployment required for low-cost capture of this existing CO_2. At the same time, they must consider further measures needed to achieve the 2050 reductions target – from efficiency improvements and fuel switching, to CCS in wider and smaller applications.

The case for ammonia

One of the suggested hurdles for early storage pilots and CO_2-EOR projects is a lack of available, high-purity CO_2 in sufficient quantities and over short timespans for use in testing the suitability of identified geological storage sites. But what if sufficient volumes were already available? Ammonia production is one industrial process which produces around 6-7Mt of CO_2 each year in Europe. This has already been separated during operations and would be available for use.

Additionally, many of these facilities are located close to North Sea coasts and could potentially be used to prove CO_2 transport and storage infrastructure. The map (*right*) provides an overview of where these sources are sited and the potential CO_2 volumes that could be drawn on for CO_2 storage pilots in the North Sea.

Graphic: P Brownsort, SCCS

Talking Points

A strategic vision for 2030

- EU strategy must encourage a global climate agreement and address carbon leakage and competitiveness
- Power plants should be anchored by co-location within industrial clusters
- Provide financial incentives for industry CCS, and a clear regulatory pathway
- Address mismatch between short-term political timescales and need for long-term policy instruments
- Support by Member States is crucial to the realisation of CCS projects

Transport issues

- Use shipping to link "lowest-hanging fruit" existing, low-cost, pure CO_2 sources with storage sites for early projects
- The development of transport infrastructure may need public authority coordination
- We must demonstrate CO_2 transport in Europe via onshore pipeline, as in North America
- Map in detail the available CO_2 sources against potential CO_2-EOR sites

Creating incentives

- Build an emissions penalty into business models for fossil fuel production, a "carbon deposit-return" system: 1 tonne produced must be matched by 1 tonne stored
- A clear timetable for tightening emissions performance standards on power plants and, in future, industrial emitters to drive investment in CCS (alongside financial incentive, retention of business and jobs, etc.)

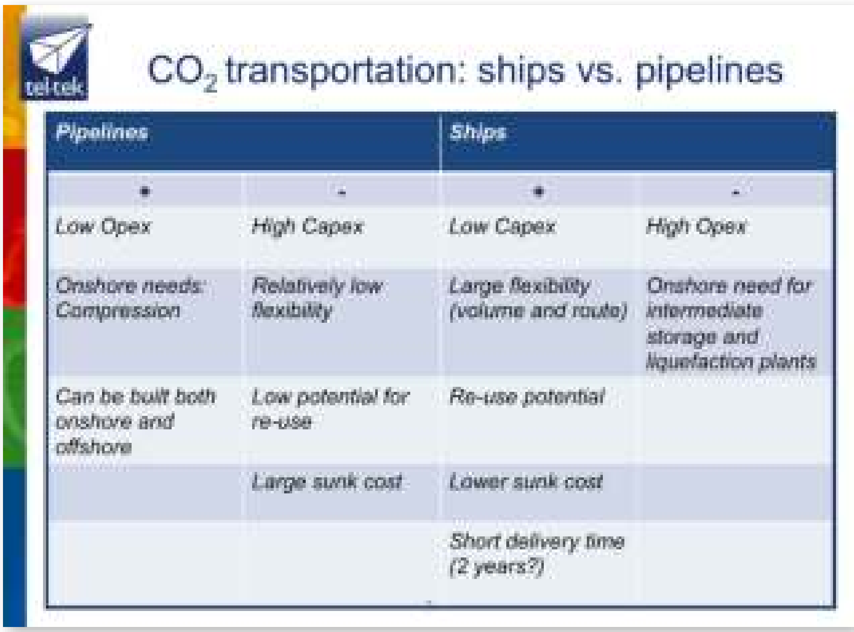
6 The link in the CCS chain

ACROSS Europe, the mitigation of CO_2 emissions from industrial sources, such as chemical plants and oil refineries, has been overlooked in favour of large and complex power generation projects. This approach has failed to attract investment due in part to the cost of the large-scale infrastructure it would require. Conference participants proposed that, instead of waiting for large-scale projects to be built, sources of high-purity CO_2 already captured by industry could be used in pre-commercial storage pilots – kickstarting the process of characterising and validating North Sea CO_2 storage assets, and initiating the creation of emitter clusters around the North Sea to form transport hubs. Discussions on CO_2 transportation therefore focused on creating those links between source and store.

Shipping and offshore infrastructure

Shipping is potentially the best method for transporting CO_2 from small-scale industrial emitters, especially during the initial development of CCS when relatively easy access to this high-purity CO_2 would allow for geological storage experience to be built more rapidly.

Hans A Haugen of Tel-Tek provided delegates with an analysis of the potential role of shipping and floating production, storage and offloading (FPSO) vessels – used by the offshore oil and gas industry – in supporting the first wave of CCS projects in the North Sea. Ships have been used for the long-distance transport of CO_2 for many decades – given its use in, for example, the food industry – so the technical experience already exists. Shipping can also provide the flexibility required to avoid heavy upfront capital expenditure in pipeline networks, as well as the logistical ease of a ship visiting multiple sources and storage sites.



CO_2 transportation: ships vs. pipelines

Pipelines		Ships	
+	-	+	-
Low Opex	High Capex	Low Capex	High Opex
Onshore needs: Compression	Relatively low flexibility	Large flexibility (volume and route)	Onshore need for intermediate storage and liquefaction plants
Can be built both onshore and offshore	Low potential for re-use	Re-use potential	
	Large sunk cost	Lower sunk cost	
		Short delivery time (2 years?)	

Hans A Haugen of Tel-Tek provided delegates with a comparison of the relative merits of ship versus pipeline transportation

But while ships may offer a solution for CO_2 transportation from ports or hubs located around the North Sea basin, CO_2 intended for storage is currently labelled as "waste" under the London Protocol and would be prohibited under cross-boundary movement regulations – an issue that will need to be addressed in order to clarify carbon credit allowances and liability for ship transport.

For initial projects, renting and retrofitting current ships for CO_2 transport was deemed the best option. The construction of new ships is expensive and can take several years, whereas the retrofit of an LNG carrier for CO_2 transport would take just two years. Global shipyards are increasingly busy due to a rising demand for renewable and gas transport assets. However, it was pointed out that ships provide less investment risk as, unlike pipelines, they can be redeployed if CCS is unsuccessful.

One area for concern was shipping rental costs, which may need to be in line with LNG transport rates as an incentive for ship operators. However, to be economically viable for the CCS industry, this rate would need to be £15 or less per tonne of CO_2.

FPSOs face the same issues as shipping over yard availability and construction times, due to an increase in hydrocarbon exploitation west of Shetland. New-build rigs cost in the region of £100m for an injection capacity of 2 million tonnes CO_2 per year. A cheaper and quicker alternative mooted by delegates was the potential use of "bespoke buoys" – offering flexibility and cost-competitiveness. These buoys have a two-year lead time, a 25-year lifetime and a price tag of £25m to construct. They would potentially require gasometer-like "buffer storage" on the seafloor for quick offloading.

The role of pipelines

The cost of CO_2 transport by ship varies little with volume and distance but, as delegates discussed, pipelines are more economical for larger volumes of CO_2 over shorter distances. A large proportion of pipeline infrastructure already in place in the UK North Sea can either accommodate or be redeployed for CO_2 transport. Around 520km of existing pipeline would allow the transport of CO_2 to hydrocarbon storage sites and their connected aquifers. A total of 150km of link additions are needed to enable this. At least four pipelines are already compliant: the St Fergus to Cruden Bay onshore link; St Fergus to Atlantic; St Fergus to Goldeneye; and St Fergus to Miller (decommissioned under condition of future CO_2-EOR use). The economies of scale for pipelines are very high, particularly below capacities of 15 million tonnes of CO_2 per year. The cost of every power station having its own offshore pipeline is prohibitive, so the creation of emitter clusters which can share transport hubs will be essential.

The Forties Pipeline System

The Forties Pipeline System is the most extensive oil transportation network in the North Sea. It services over 70 hydrocarbon fields via several key anchor fields, including Brent and Forties. Operating costs are in the region of £90-100m per year, including the offshore Main Oil Line pumps, unity riser platform (allowing many third-party fields access), onshore pipeline, terminal, and export facilities. Infrastructure such as this will be a valuable asset to a North Sea CCS industry.

Graphic: Prospects for activity in UKCS over next 30 years, *A Kemp, Global Energy Systems Conference, 2013*

Looking to exemplars beyond Europe, pipelines transporting CO_2 in the USA largely support EOR operations. Significant private investment in CO_2-EOR fields and their associated infrastructure during the 1980s led to the construction of 60% of the existing 3,900-mile USA pipeline network. Investment was largely encouraged by state and federal incentives, such as infrastructure tax credits, windfall profit taxes on existing EOR fields and tax incentives related to the value of incremental oil produced. CO_2-EOR is considered an attractive business model for CO_2 storage because oil revenue could significantly reduce costs of the entire CCS chain, including transport. The major challenge for CO_2-EOR is providing a guaranteed supply and consistent volume of CO_2. It is generally accepted that North Sea CO_2-EOR would require at least 5 million tonnes of CO_2 per year to be sustainable. This would likely require a major CO_2-ready transport pipeline to accommodate multiple emission sources.

Talking Points

Technical aspects

- Shipping will need adequate onshore storage and compression facilities
- Liquefying CO_2 for shipping has an inherent energy penalty

Shipping

- Shipping provides flexibility to test different storage options for early storage projects without committing to costly pipelines
- Ships allow links between a greater number and variety of source locations
- CCS will compete for ships with high demand from renewables, food industry and the shale gas boom

Economics and regulations

- CO_2-EOR monetises CO_2 so it can provide a mechanism for transporting CO_2 across borders
- Safe transport of CO_2 is already proven by food industry operations
- Ease of insurance where multiple operators and potentially complex operations involved

7 Tapping into North Sea CO_2 storage

FOR CCS to play a significant part in reducing the EU's carbon emissions, Member States will need validated storage capacity. This will need to be easy to access and economically viable. In the IEA's 2D scenario, outlined by Dr Simon Bennett during the conference, Europe must store 310Mt of CO_2 each year by 2030, rising steadily to 680Mt each year by 2050. Delegates considered this achievable if the CCS community focuses its efforts on establishing the necessary North Sea CO_2 storage infrastructure.

The North Sea has a wealth of potential storage sites with the capacity to meet Europe's targets, and continue CO_2 storage far beyond 2050 (see panel *A vital storage asset, page 35*). However, there is a need to translate these resources into commercially proven storage reserves. Within the conference break-out sessions, delegates tackled this fundamental issue to suggest practical actions within the next five years to achieve these objectives.

The pre-commercial evaluation and development of storage sites in the North Sea is seen as critical. It is often forgotten that the availability of storage must be proven before a project starts, and must have the capacity for the full tonnage of CO_2 expected for that project during its 15-30 year lifespan. Practical knowledge gained at the pre-commercial stage is a "public good" lacking from individual commercial projects. ZEP and others have already suggested that six CO_2 storage pilots should be operational by 2020, above and beyond the current commercial-scale projects. These pre-commercial projects should include CO_2-EOR as well as confirming theoretical capacity estimates of saline aquifers, with small-scale injection tests using industrial CO_2 streams.

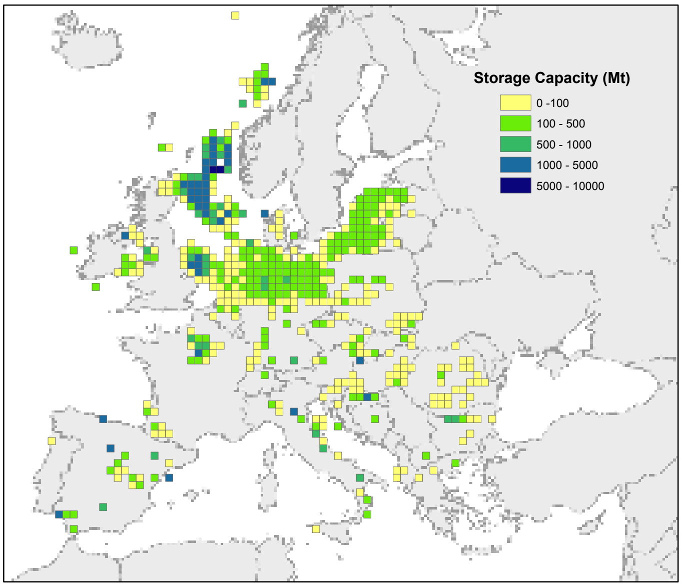


Figure 7: *A 2010 study by ARUP identified CO_2 storage sites and volumes around Europe, including the North Sea basin. Graphic:* Feasibility study for Europe-wide CO_2 infrastructures*, Haszeldine et al, ARUP, 2010*

As already outlined (see *Chapter 5: Sourcing CO_2 to accelerate storage, page 27*) industrial processes can provide existing sources of pure CO_2 at very low cost, which can offset the costs normally associated with capture. At the volumes envisaged, CO_2 could be delivered by ship to multiple sites in order to perform injectivity tests (see *Chapter 6: The link in the CCS chain, page 30*). The value of developing pilot tests of 100,000 tonnes or less was also considered useful in order to avoid any permitting delays, such as for cross-boundary transport or liability.

The benefits of having an onshore CO_2 injection pilot project were discussed, with experience being shared by Prof Peter Cook. He explained that one of the major benefits of the Otway project in Australia was that multiple stakeholders could engage with a real project and "kick the tyres". Politicians, regulators and the general public can all gain enhanced understanding of CCS by observing operations. The development of monitoring techniques could also inform regulation and help to reduce costs associated with commercial-scale projects.

Prof Niels Peter Christensen, of Gassnova, who had earlier described the detailed process of evaluating saline aquifer sites for Norway's Mongstad CCS project, suggested that there would be cost-reduction benefits to Europe if it moved towards developing one or two large-scale North Sea saline aquifer stores – as a shared storage resource among European nations.

Dr Heike Rütters of BGR shares key findings from the CO_2GeoNet report, The state of play on geological storage in 28 European countries: an overview

Finance mechanisms and clarity over liability for pre-commercial projects were viewed as vital for the rolling out of projects within the EU. Prof Alex Kemp, of the University of Aberdeen, stressed the need for tax incentives for EOR. With the current UK tax rate on most potential North Sea CO_2-EOR fields set at 81%, he pointed out that the UK Treasury provides a brownfield tax allowance for the further development of existing oil fields that does not yet apply to CO_2-EOR. In contrast, Eric Redman of Summit Power explained that tax rates on conventional oil production in Texas, USA, are just 4.6%, with a reduced rate of 1.15% when using anthropogenic CO_2-EOR.

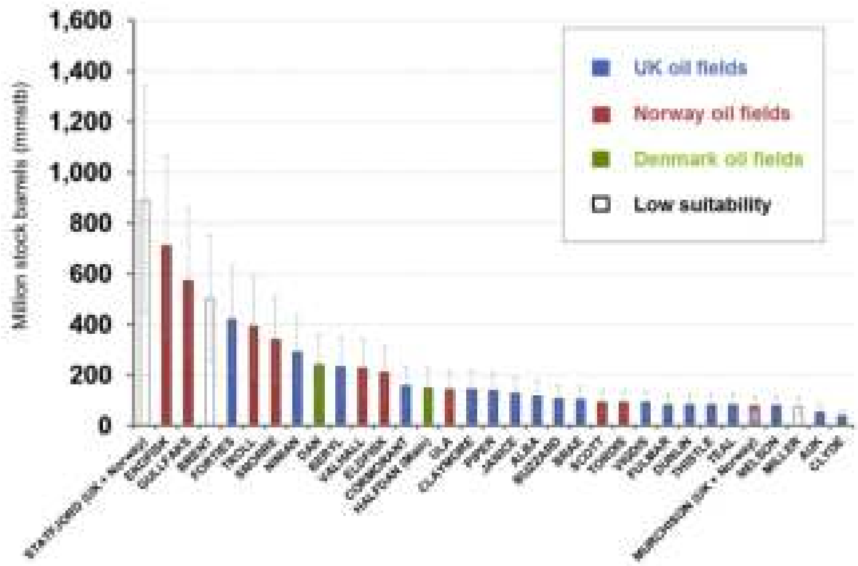
The sequential deployment of CO_2 storage pilots is possible in depleted hydrocarbon fields as they become available due to decommissioning. This has scope to reduce the cost of both the characterisation of storage sites and project operation through the use of existing/recycled infrastructure. Storage in these fields can then progress later to geologically connected saline aquifer projects. Decades of exploration, operation and production history data exist for the North Sea hydrocarbon fields, which could be used for early characterisation projects. However, this data is often held commercially, and a large portion of discussion amongst delegates was about greater collaboration and knowledge exchange – using derived information – between industry, research providers and government.

Prof Alex Kemp of the University of Aberdeen explores a CO_2-EOR case study, looking at the potential for a cluster development in the Central North Sea

This sharing of knowledge could not only reduce costs for individual projects but would also pave the way for creating clusters of storage sites and potential multi-user stores, with appropriate cost-sharing between projects. One suggestion was to tie such information-sharing activities to hydrocarbon extraction permits. The data, obtained during exploration and production, would therefore not be an extra burden on the operator beyond that of making it accessible to future CO_2 storage operators – and only upon decommissioning of the field. In-depth discussion with commercial operators was advised.

The break-out sessions emphasised the need for a "bottom up" development of pilot projects, whereby the research community, industry and governments work together to expand on the currently limited remit of the North Sea Basin Task Force (NSBTF).

It was noted that the North Sea oil and gas sector has, for many years, underpinned the economies around the North Sea basin. The creation of a CCS industry in the UK alone could create 27,000 jobs by 2020, provide future skilled employment for existing oil and gas sector workers and boost the economy by around £10bn a year by 2025[1]. Achieving this will depend, however, on sustained support for a CCS programme by both government and industry.



The decommissioning and closure of large North Sea oilfields with the potential for CO_2 Enhanced Oil Recovery (CO_2-EOR) operations, such as those above, will soon put many of these out of reach for maximising the region's CO_2 storage potential. Graph: Economic impacts of CO_2-enhanced oil recovery for Scotland, *Element Energy/Heriot-Watt University, 2012*

A VITAL STORAGE ASSET

As recent studies suggest, the North Sea has an array of suitable storage sites with an estimated total CO_2 capacity of 160 gigatonnes. These include saline aquifers, depleted hydrocarbon fields that are well characterised, and the potential for CO_2 storage as part of enhanced oil recovery projects.

Saline aquifers alone represent gigatonnes of CO_2 storage potential. The relevance to EU needs of Scotland's North Sea capacity has been underlined by two reports assessing the Captain Sandstone – which could hold around 360Mt of CO_2[1]. Norway published its second storage atlas earlier this year, which suggests the Norwegian Sea could store around 5.5Gt of CO_2, in addition to 67Gt already identified in Norway's North Sea[2].

The North Sea's suitability as a storage hub is enhanced by an existing oil and gas sector infrastructure – ports, pipelines and platforms – that can be modified for CCS operations serving, at the very least, the North Sea states but with the potential to widen the net to other EU Member States. Depleted hydrocarbon fields offer an accessible and well-characterised range of storage sites, which are due to shut down operations – and so become available for CO_2 storage – over the next decade.

[1] *Progressing Scotland's CO_2 storage opportunities*, SCCS, 2011
[2] *CO_2 Storage Atlas Norwegian North Sea*, NPD, 2011

Talking Points

Financing pilots

- Member States could share both risk and cost for first pilots
- Would near-shore injection lower cost and create public engagement opportunities?

Accessing CO_2 sources

- Greater cross-border cooperation needed, with emphasis on CO_2-EOR with storage
- CO_2 from Norway's Sleipner project could be used to test CO_2-EOR at pilot scale

Collective activity

- A research consortium approach with government support would enable first pilots
- Should strategic planning identify large-scale infrastructure, funded and built for the public good?

Risk and liability

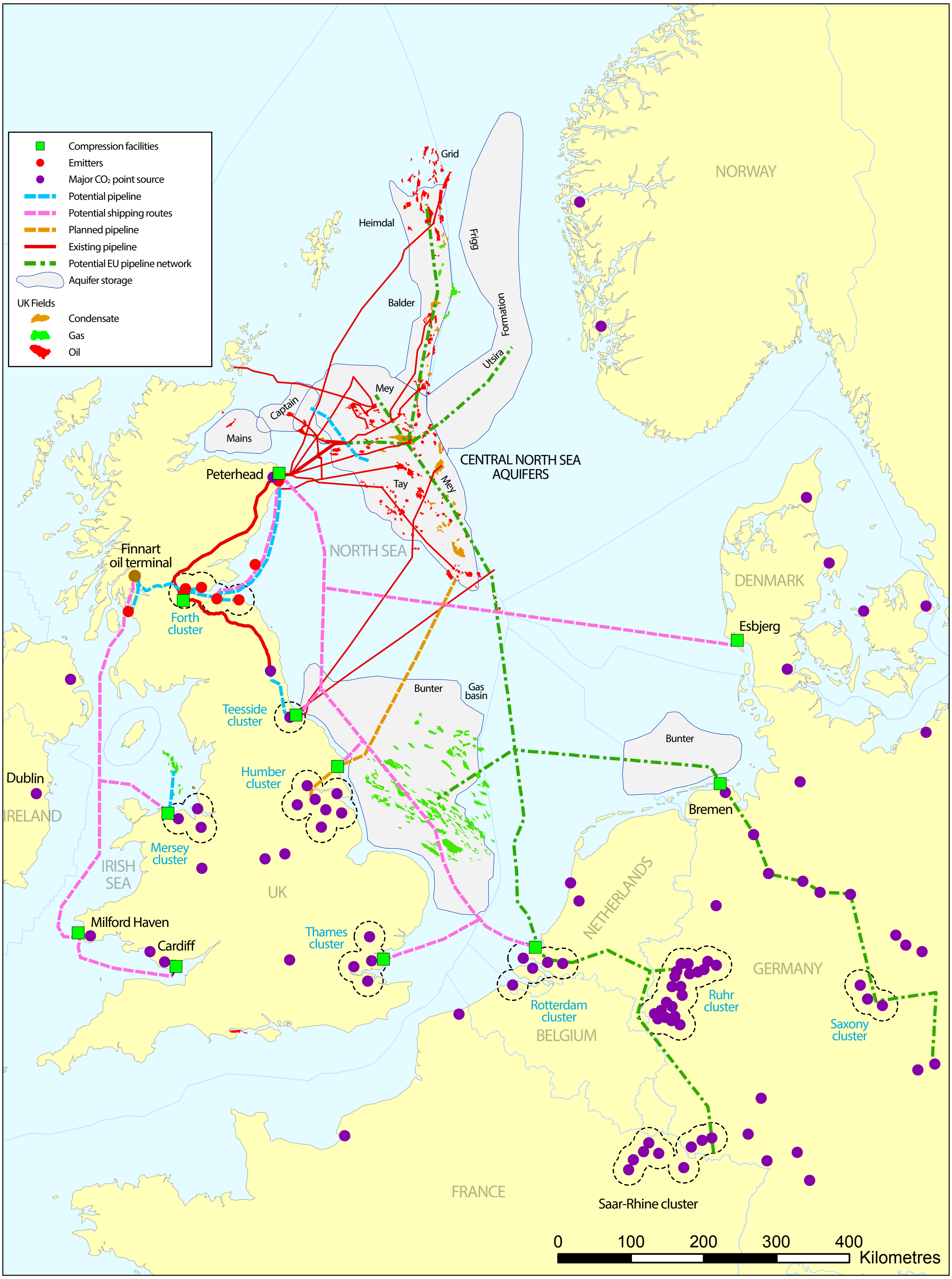
- Could risk be handled by a European risk-sharing mechanism?
- Risk profile analysis for storage (such as The Crown Estate's CO_2Stored storage evaluation database) would be useful

Cost reduction and knowledge sharing

- Use of depleted fields helps operators defer decommissioning costs
- Sharing of knowledge regionally can reduce validation costs

Achieving second-wave CCS, post-2020

- First projects should identify research requirements for next phase
- Penalties on CO_2 emissions could fund subsequent projects ahead of mandatory CCS



A vision for CCS in the North Sea, highlighting existing and potential CO_2 transport and storage opportunities
Source: Central North Sea – CO_2 Storage Hub, *SCCS, 2012*

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SCCS is a research partnership of British Geological Survey, Heriot-Watt University and the University of Edinburgh. Our researchers are engaged in high-level CCS research as well as joint projects with industry, with the aim of supporting the development and eventual commercialisation of CCS in the UK and abroad. **www.sccs.org.uk**