

2015 Situation Report on the European Large Scale Demonstration Projects Network: Public Summary

Public version

Executive Summary

Established in 2009, the European CCS Demonstration Project Network (The Network), has been a unique knowledge-sharing effort aimed towards development and deployment of the CCS technology. The Network currently consists of four CCS projects in Europe: former Compostilla (Spain), Don Valley (UK), ROAD (The Netherlands) and Sleipner (Norway).

This is the third report of a series that cover technology progress of different parts of the CCS chain, updates on regulatory developments, summary of efforts related public engagement, costs and knowledge-sharing beyond the Network. Information in this report is based on aggregate information that projects released at the knowledge sharing events as well as through the Information and Experience Gathering (IEG) survey, a Network-developed tool for knowledge sharing.

Little has changed for the projects in terms of planning and following project timelines since EU CCS Network Situation Report 2013/14 was released. The common theme seems to be that projects have experienced delays with various permits and in reaching a final investment decision (FID).

The Network is composed of mainly power projects and a gas processing project (Sleipner). Sleipner is the only project currently in operation.

Three projects (Don Valley, ROAD and Sleipner) use, or intend to use offshore pipelines. For storage, a variety of storage sites are being used or investigated, ranging from onshore saline formations, to offshore depleted gas reservoirs and enhanced oil recovery (EOR operations).

In December 2014 the Don Valley project was acquired by Sargas Power Yorkshire Limited. The ROAD project proponents are now looking for additional funding in order to proceed with the Final Investment Decision (FID). The Peterhead CCS project joined the Network in mid-November 2015. Nevertheless, the project was terminated because of the cancellation of the UK CCS Commercialisation Competition, which could have provided up to £1bn funding to Peterhead and White Rose CCS projects.

Securing funding for these initial large-scale CCS projects continues to be a key challenge to deployment of the technology across Europe. Globally there is a growing awareness of the importance of investing in infrastructure and research on low-carbon technologies such as CCS. However, it is the funding challenges that are slowing down wide scale deployment of the technology in Europe, and are threatening to significantly increase the cost of decarbonisation of the European economy.

Network projects differ in designs, volumes, locations, etc. The information presented in this report is not normalised, hence should be used with caution. Please contact the Secretariat if any discrepancies are discovered.

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Introduction

In 2009 the European Commission (EC) established the European CCS Demonstration Project Network (the Network) to accelerate the deployment of commercially viable large-scale CCS projects across Europe. The Network was created to support knowledge and experience sharing among this community of European projects. Since 2009, knowledge and experience-sharing has not been limited to technical progress and it has also been focusing on policy and regulatory development.

The European CCS Demonstration Project Network: Situation Report 2015 provides aggregated data and key findings, as well as lessons learnt by the projects in the past 12 months (2014-2015). The goal of this report is to provide holistic, useful and up to date information on the Network projects and the lessons drawn from the project development.

The Network is made of a unique collection of large scale, early-mover CCS projects. However, the overall project development progress has been difficult for a number of reasons, such as a lack of CCS enabling policies on the national level and lack of financial support. One of the goals of the Network is to create and facilitate a community of individual projects that can share solutions to problems encountered.

Any interpretation or misinterpretation of the data contained within the body of this report is the Secretariat's responsibility. Informing us of any inaccuracies is appreciated and encouraged.

The role of CCS

Climate scientists and parties to the UNFCCC agreed that global temperature change should be limited to below 2.0 °C (3.6 °F) relative to the pre-industrial level “to prevent dangerous anthropogenic interference with the climate system”, and that this effort requires deep cuts in Greenhouse Gas (GHG) emissions.¹ In December 2015, at the 21st Conference (COP 21), Parties agreed to set an even more ambitious target: to hold the increase of the global average temperature to well below 2°C, and pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels. Making the target more stringent than the previous 2°C, strengthens the case for a need for deep-cut technologies such as carbon capture and storage (CCS). Deep reductions are needed not only in the power sector, but also in industry, where the decarbonisation options are more limited.

The IEA Technology Roadmap for CCS (IEA, 2009) suggests that the costs to halve emissions by 2050 will rise by 70% in the electricity sector if CCS is not implemented.² Under existing and proposed new policy commitments, the 2°C limit is not be achievable. IEA proposes that the policy actions required to achieve the 2°C limit (the 2DS scenario) will require 14% of the total abatement of emissions to come from CCS by 2050.

The European Commission’s Communication on the Future of Carbon Capture and Storage in Europe published in 2013, also acknowledges that capital costs to reach the greenhouse gas targets required for a maximum rise in global temperatures in the power sector might increase as much as 40% without CCS.³

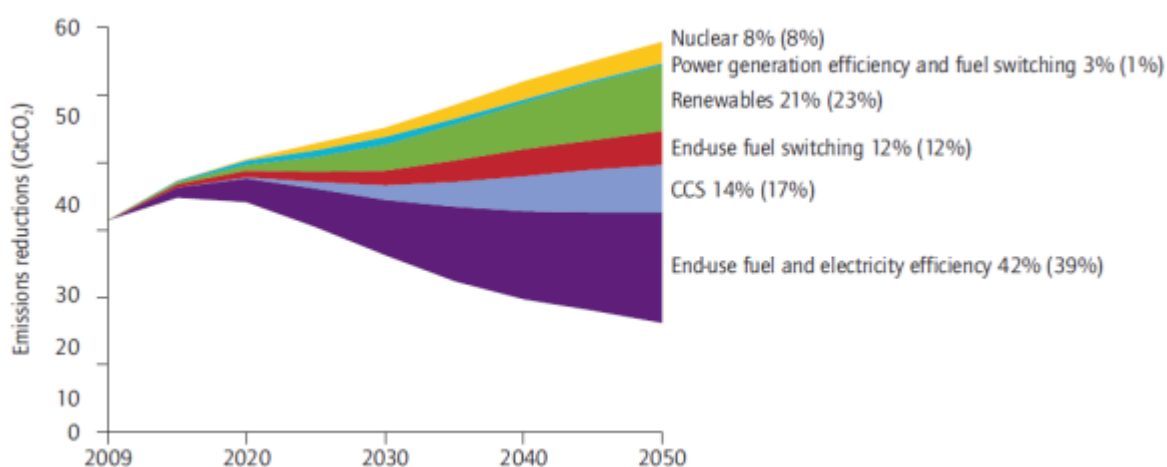


Figure 1. Global CO₂ emissions reduction by technology (Source: IEA, 2013)

In its Energy Roadmap 2050, the European Commission, proposed a number of different scenarios to meet stringent 2050 emissions reduction targets.⁴ Four out of the five decarbonisation scenarios

¹ http://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf

² IEA, 2009. *Technology Roadmap: Carbon Capture and Storage*.

<http://www.iea.org/publications/freepublications/publication/technology-roadmap-carbon-capture-and-storage-2009.html>

³ COM(2013) 180 final. Brussels, 2013. <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2013:0180:FIN>

⁴ *Energy Roadmap 2050*, The European Commission: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0885:FIN:EN:PDF>

proposed require a significant contribution from CCS, with a contribution of up to 32% in power generation in the case of constrained nuclear production. The only scenario proposed without CCS relies on 97% of the electricity consumption being produced from renewables. This scenario, however, would require large volume of electricity storage, which would require further development.

It is also worth noting that the Energy Roadmap solely focuses on energy generation. CCS and Carbon Capture and Usage Storage (CCUS) are the only available technologies that can reduce emissions from the industrial sector (steel, cement, gas processing, refining, paper and pulp and other heavy industries). Moreover, the use of sustainable biomass together with CCS is the only available technology that can be 'CO₂ negative' and effectively extract CO₂ from the atmosphere.

In its Roadmap for moving to a competitive low-carbon economy in 2050, the European Commission suggests that "if investments in low carbon technology are postponed, they will cost more from 2011 to 2050 and will create greater disruption in the longer term". This is highlighting the need for CCS to be demonstrated and implemented without delay.⁵

Finally, the latest report released from the IPCC working group III⁶ highlights that the mitigation scenarios⁷ that reach atmospheric concentrations of about 450ppm CO₂eq by 2100 entail mitigation costs that can increase substantially if CCS is not considered.

CCS, therefore, can become a game-changing technology for tackling climate change, while maintaining sustainable and flexible industrial opportunities. CCS applications are expected to form a market to be worth trillions (SINTEF, 2013) allowing job retention and creation in multiple industrial areas within Europe.

The European CCS Demonstration Project Network

The successful operation of CCS demonstration projects is seen as crucial for enabling widespread commercial application of zero emission power plants and industrial installations, to meet the European Union and global emission reduction goals.

The Network originally consisted of six large scale projects, to which the EC allocated €1 billion through the European Energy Program for Recovery (EEPR). In parallel, the EC established the EU CCS Network to support these projects by:

- Identifying good practices, lessons learnt and recommendations for large-scale project development
- Providing a common EU identity to Network Members
- Promoting CCS, EU leadership and cooperation potential to third parties/countries
- Supporting the creation of a global network on CCS project development

All projects that apply for membership of the Network provide evidence about the maturity of the project, commit to knowledge sharing and actively participate in the Network organisation and procedures. The Network foresees to include non-project entities as associate members. These

⁵ Roadmap for moving to a competitive low-carbon economy in 2050, The European Commission: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0112:FIN:EN:HTML>

⁶ IPCC, 2014: Summary for Policymakers, In: Climate Change 2014, Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

⁷ Under the absence or limited availability of technologies.

entities have to demonstrate an interest in deploying CCS and have relevant current data that aids near-term deployment. The Crown Estate, an organization that manages lands and holdings of the United Kingdom, is an associate member active in CO₂ storage developments.

How the Network has changed in 2015

The EU CCS Network Secretariat is a consortium composed by The Global CCS Institute, the Netherlands Organisation for Applied Scientific Research (TNO) and the Foundation for Scientific and Industrial Research (SINTEF):

- The Global CCS Institute is an international membership organisation, which promotes the adoption of CCS by sharing expertise, building capacity and providing advice and support
- TNO is an independent research organisation, which intends to create innovation that boost the competitive strength of industry and the well-being of society in a sustainable way
- SINTEF is an independent research organisation that aims at developing society through research and innovation
- BRGM is a public institution focused on Earth Science applications in the management of surface and subsurface resources and risks

In March 2016 France's national Geological Survey (Bureau de Recherches Géologiques et Minières - BRGM) will join the Network to work on the storage section. The French Geological Survey will replace IFP Energies nouvelles (IFPEN) that was a part of the Network Secretariat till 2014. All four partners of the secretariat have worked well together, pooling expertise and cooperating on all tasks.

The Peterhead CCS Project joined the Network in mid-November 2015. Nevertheless, following the latest UK Government spending review announcement of 25 November, the funding that the CCS commercialisation competition could have provided to the Peterhead project was withdrawn. Shell U.K. Limited, the project proponent, will honour its remaining commitment under the Front End Engineering and Design (FEED) contract it entered into with the UK Government in 2014, but it announced that the project will not proceed further.

European demonstration Network member's overview

Compostilla

Summary

The Compostilla project was to be located in El Bierzo, Spain. The project operator was Endesa, in partnership with Ciuden and Foster Wheeler. The OXYCFB 300 Compostilla Project, completed the work that it had committed to carry out under the terms of its EEPR grant by October 2013. Subsequently it took a decision not to proceed to full-scale demonstration because of regulatory and economic obstacles. The Project would operate on a 300 MWe Circulating Fluidised Bed (CFB) supercritical oxy-fuel coal-fired power plant. The plant would be constructed next to the existing coal-fired power plant of Compostilla. The CO₂ capture efficiency could be 91%. The CO₂ captured would be transported by a 120km pipeline to an onshore deep saline formation. The project could store 1.6 MtCO₂/year.



Progress during 2014-2015

- The Compostilla project have decided not to go ahead with the next step in the project, which would have been an integrated industrial-scale CCS demonstration plant;
- The project's storage component continues operations in Hontomín. The Hontomín Technology Development Plant is located in Northern Spain.

Don Valley

Summary

The Don Valley project (DVPP) is based in Yorkshire, UK. The project was acquired by Sargas Power Yorkshire Limited in December 2014. The DVPP was first launched by Powerfuel Power Limited and its partner National Grid in 2008 before being purchased by 2Co Energy in 2011.



Sargas Power Yorkshire Limited is responsible for the power generation and capture plant, while National Grid (the Yorkshire and Humber CCS Cross Country Pipeline) is responsible for the onshore and offshore transport system and saline storage site. DVPP will deliver 1.5 million tonnes of CO₂ per annum into the pipeline network. Storage of CO₂ from Don Valley is to be in conjunction with CO₂ captured from other Yorkshire projects, such as the White Rose CCS Project.

Progress during 2014-2015

- Change of ownership from 2Co Energy to Sargas Power Limited in late December 2014;
- The project intends to negotiate with DECC an individual Contract for Difference to help support the project when operational.

ROAD

Summary

The ROAD project is based in the Port of Rotterdam, Netherlands. The project is a 50:50 joint venture between Uniper (previously E.ON Benelux) and ENGIE Energie Nederland (previously GDF SUEZ Energie Nederland). TAQA Energy B.V. will provide CO₂ injection and permanent CO₂ storage. The project will apply post combustion capture to a 250 MW slipstream from new 1,070 GW coal and biomass power plant. The project is expected to capture 1.1 MtCO₂/year. The CO₂ captured will be transported in a 26 km pipeline to offshore depleted gas reservoirs which are located in block P18 of the Dutch continental shelf. The ROAD project is now also considering an alternative storage site, the Q-16 Maas field, in collaboration with the operator, Oranje-Nassau Energie.



Progress during 2014-2015

- The storage permit will need to be updated before injection starts (in particular monitoring plan, corrective measures and financial security will be reviewed);
- ROAD project has been looking at the Q-16 Maas as an alternative storage option.

Sleipner

Summary

The Sleipner Project is based in the North Sea 250 kilometres west of Stavanger, Norway. The project operator is Statoil in partnership with Total and Exxon Mobil. The development embraces the Sleipner East and Sleipner West gas and condensate fields (and tie-ins from a number of satellite fields). It is a gas processing project, the only non-power project in the Network. The natural gas produced at the field is stripped via a conventional amine capture of its high (~9%) CO₂ content. The CO₂ stream is then directly injected into a deep saline aquifer via a 1km pipeline. The project has captured more than 16 Mt of CO₂ since it started operating in 1996.



Progress during 2014-2015

- As of April 2014, the CO₂ capture facilities at Sleipner T process an additional volume of CO₂ associated with gas production from the Gudrun field, which ties in to the facilities on Sleipner East;
- An extensive program to monitor and model the distribution of injected CO₂ in the Utsira Formation is in place. This program includes a baseline 3D seismic survey and eight time lapse (4D) seismic surveys, three seabed microgravimetric surveys, one electromagnetics survey and two seabed imaging surveys.

Peterhead

Summary

The Peterhead project was to be developed by Shell U.K. Limited, with strategic support from SSE Ltd., to capture and store CO₂ from the Peterhead Power Station – an existing natural gas fired power station in Aberdeenshire, Scotland. Shell would have been responsible for designing and constructing the CO₂ capture plant and for the operation, transport and storage elements of the project. SSE would have provided the generation facilities, utilities and the flue gas from which the CO₂ could have been extracted.

Approximately 10 to 15 million tonnes of CO₂ were expected to be stored over the anticipated (10 to 15 year) life of the Peterhead CCS Project, with injection that was expected to commence from 2019.

In 2012 the UK Government selected Peterhead as one of four successful projects shortlisted to continue to the next stage of its £1 billion CCS Commercialisation Programme. In 2013 the Peterhead CCS Project was chosen as one of two preferred bidders eligible for capital funding available under the CCS Commercialisation Programme to undertake FEED studies over the following 18 months.

Progress during 2014-2015

- The UK Government awarded Shell U.K. Limited with a ‘multi-million pound’ FEED contract for its Peterhead CCS Project in February 2014;
- Following the announcement by the UK Government, on November 25th 2015, of the withdrawal of funding for the CCS Commercialisation Competition, the project will not proceed to further stages.

Project Quick Reference

Table 1. CCS project quick reference table (All available data displayed)

	Don Valley	ROAD	Sleipner *
Production plant type/CO ₂ source	Power plant	Power plant	Natural gas processing
Installed production capacity	552 MWe (gross)	1069MWe (power plant) 250 MWe (slip stream to capture plant)	N/A
Fuel Type (for power production)	Natural gas	Coal (with biomass co-firing planned)	N/A
Capture Type	Post-combustion	Post-combustion	Industrial separation
Transport Pipeline Length (km)	175	6 (onshore)	1
Storage Type	Offshore saline aquifer	Offshore depleted oil and/or gas reservoir	Offshore saline aquifer
Planned CO ₂ Capture/Stored (Mt/yr)	Up to 1.5	1.1	0.9

*Project in operation

Capture technologies in the Network

Status Brief

- ✓ Don Valley project opts for Integrated Pressurised Capture Technology (IPCT) to capture up to 1.5 million tonnes of CO₂ per annum (Mtpa).
- ✓ The ROAD project described how the power plant water streams are minimised and where possible reused, examining the implications for overall site water consumption and for full-scale carbon capture.
- ✓ Sleipner project continues amines operations for CO₂ capture, adding knowledge to the already 20 years' experience of the project.

Project summary

The **Don Valley** was acquired by Sargas Power in December 2014. The change of ownership resulted in change of the project technology and configuration. The current configuration intends to use Integrated Pressurised Capture Technology (IPCT) to capture 90% of the CO₂ from the flue gas.

The **ROAD** project has finalised the design of the capture unit. The CO₂ capture technology will be using primary amines in post-combustion. ROAD's capture plant is the Econamine FG+ process of Fluor. This is a partial capture unit, taking part of the flue gas from the power plant as a slip stream for CO₂ capture. 90% of the CO₂ is captured from the slip stream, with the cleaned flue gas being returned to the stack. The project completed detailed engineering of the plant.

Sleipner, the only non-power project in the Network, is an offshore natural gas processing project operating since 1996 and capturing nearly 0.9 Mtpa of CO₂ from its natural gas field. The project operator needs to reduce the CO₂ content of the produced gas in compliance with the commercial requirements of the European natural gas system. To do this, Sleipner makes use of an advanced amine high-pressure absorption/desorption technique without fuel conversion (i.e. no combustion).

All Network projects use or intend to use solvents for CO₂ capture from feed streams that require treatment.

Don Valley and ROAD projects have introduced changes and contributed to significant knowledge during 2014/15, while Sleipner continues to successfully operate. The following paragraphs focus on each project individually.

Integrated Pressurised Capture Technology (IPCT) in Don Valley

Sargas AS has proposed a system of well-established and proved technologies, by combining the advantage of the pressurised fluidised bed combustion technology (PFBC) with pressurised post-combustion carbon dioxide capture. The idea is a) to provide a high partial pressure of the CO₂ to allow

for low-cost chemicals (e.g. carbonates) for efficient flue gas cleaning, and b) to apply a high degree of process integration to form an integral power scheme to facilitate CCS.⁸

As partly depicted in Figure 3, air leaving the compressor is burned with natural gas in front of a gas-pressurized heat recovery steam generator. Cooling with water- and steam-cooled tubes allows essentially all of the air to be used for combustion. This results in a combustion gas CO₂ content of approximately 12% rather than the 5% more commonly found in combustion turbine exhaust.

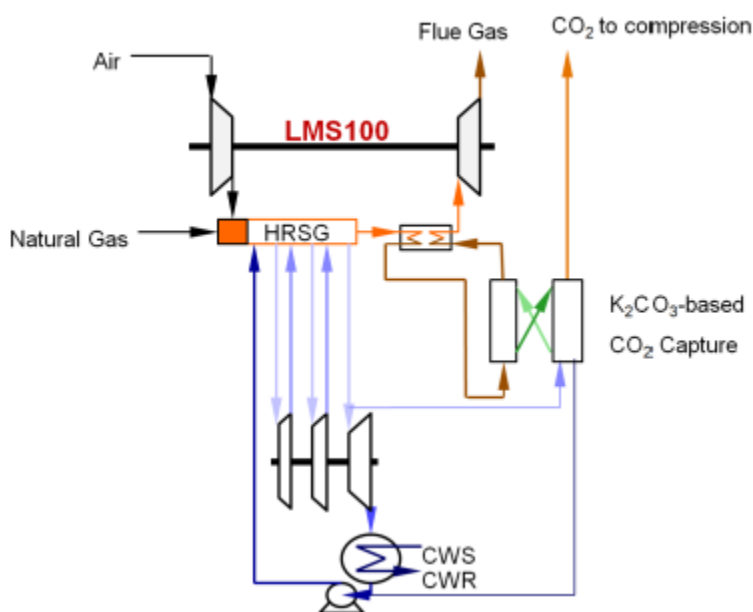


Figure 2. Simplified schematic of the Sargass technology⁹

CO₂ is removed at pressure from the combustion gases using a post-combustion CO₂ capture process, employing potassium carbonate as a solvent. Removing the CO₂ at pressure reduces the size and cost of the post combustion capture plant as does the higher CO₂ concentration. An inlet-outlet recuperator is utilized to cool the combustion gas to the CO₂ capture temperature and then re-heat it prior to expansion in the gas turbine.

CO₂ capture unit

The CO₂ capture unit employs the hot potassium carbonate process - a chemical absorption, thermally regenerated cyclical solvent process that uses an activated hot potassium carbonate solution for removing CO₂.¹⁰

⁸ Hetland J., Christensen, T., (2008). [Applied Thermal Engineering](#), Volume 28, Issue 16, Pages 2030–2038.

⁹ Thimsen, D., 2014. USEA Workshop on Technology Pathways Forward for Carbon Capture and Storage on Natural Gas Power Systems. Available at : <http://www.usea.org/sites/default/files/event-/Thimsen%202014-04-22%20USEA%20Oxy-Natural%20Gas.pdf> (accessed at 30.09.15)

¹⁰ UOP LLC: Increasing Efficiency of Hot Potassium Carbonate CO₂ Removal Systems, <http://www.uop.com/?document=increasing-efficiency-of-hot-potassium-carbonate-co2-removal-systems&download=1> (accessed 4.8.15).

The Sargas Power plant will provisionally consist of two Sargas Stargate 250 IPCT units generating approximately 520MW of electricity (net). 90% of the CO₂ will be captured from the pressurised system to deliver CO₂ into the pipeline network.

Water usage in ROAD

Water usage is always a concern for power plant designers as it is estimated that plant facilities are to use considerable amounts.¹¹ The addition of carbon capture to a power plant significantly alters water usage in the overall plant and therefore is an important factor when considering applying CCS.

ROAD conducted a study describing the water consumption and waste water streams for the power plant as well as for the carbon capture plant design.¹² It found that the majority of waste water from the capture plant can be re-used. To minimise the Cooling Water (CW) flow in the capture plant, the study considered maximizing heat integration by utilising streams of the stripper overhead condenser. The study considered different options for the cooling water integration.

Another stream that can be utilised is the excess water collected in the Direct Contact Cooler (DCC) which is the largest “waste” stream from the capture plant. The capture plant also produces three smaller waste streams that can be reused where possible, but handled properly. The project has been examining available options for effectively utilising those streams.

In conclusion, the addition of the ROAD carbon capture plant increases the cooling water usage at the main power plant. However, where seawater cooling is available, this increase has a much more limited impact. The carbon capture plant recovers substantial quantities of water from the flue gas due to the additional cooling required. These can be used to cover other water needs within the process. Extrapolating from the ROAD design, full-scale capture would allow water usage of the power plant except for cooling water, nearly eliminating the need for freshwater supply.

ROAD’s findings are a significant contribution to knowledge as the implications of CCS in water use, have been an ongoing concern amongst the scientific community.

¹¹ DOE/NETL-2010/1397

¹² Hylkema, H., Read, A., (2014). Energy Procedia 63, p. 7187 – 7197

Transport

Status Brief

- ✓ The Network projects use or intend to use primarily offshore pipelines
- ✓ Pipeline length can be as short as 25 km for power projects
- ✓ The projects have made significant efforts to justify their CO₂ transportation systems as required by the permit-granting process

Transportation of CO₂ and other gases has been occurring for decades in many parts of the world and is not expected to be a major barrier to CCS.¹³

All of the Network's projects are using or planning to use pipelines to deliver the captured CO₂ to the storage sites. Don Valley and ROAD require offshore, subsea pipelines to reach the storage location. Sleipner is already using a subsea pipeline. The power projects, will use a pipeline under 200 km in length.

The Network projects have made significant efforts towards their CO₂ transportation systems permit process. This includes assessment of CO₂ release dispersion, fracture control measures, materials behaviour, thermophysical characterisation of pure CO₂ and CO₂- rich mixtures, flow assurance, environmental impacts, identification of hazards, quantitative risk assessment (QRA), and front-end engineering design (FEED) studies.¹⁴

Compression work

Compression work is reported from the Network projects as the required power per ton CO₂ compressed. The compression work is estimated taking into account different assumptions such as different concentrations of impurities in the CO₂ stream. Additionally, the design of the compression train, especially the number of compressor stages, interstitial cooling (temperature and pressure drop), and the level of dehydration of the CO₂ stream, as well as the use of CO₂ pumping instead of compression beyond the critical pressure can affect the compression work.

Pipeline flow

Maintaining single-phase flow in a pipeline can be important as having two phases may present problems for compressors and transport (valves and metering) equipment, due to 'slugging', density changes, vibration and fatigue. The longer the pipeline, the more useful it is to use high density CO₂. Using low density CO₂ will require a much larger pipeline diameter for the same flow rate. However, the higher the density of CO₂ required, the more compression work is needed before and during transportation. The ROAD project, which has the shortest pipeline of the power projects, is expecting to have the lowest initial flow rate through its existing pipeline. One of the other key considerations for all elements of CCS and in particular transport, is the issue of CO₂ composition as it influences the design of the pipeline network.

¹³ Intergovernmental Panel on Climate Change: *Special Report on Carbon Dioxide Capture and Storage* (2005).

¹⁴ Jens Hetland et al. / *Energy Procedia* 63 (2014) 2458 – 2466

All three projects have conducted rigorous flow assurance studies. The main conclusion is that transporting CO₂ through a pipeline system at nominal conditions is rather simple. For economic reasons, the projects independently decided that the CO₂ should be transported in the dense phase.

At the outset, however, the ROAD project will transport the CO₂ in gaseous phase because of the very low initial reservoir pressure. Although the specific volume of the flowing CO₂ will then be substantially higher, the pipeline has been sized to allow this. Rather than operating above the critical pressure, the pipeline system of the ROAD project will operate at a temperature well above the critical temperature for CO₂ (i.e. 31.1°C). This is made feasible by reducing the cooling at the outlet of the compression train. Warm CO₂ will then enter the transportation system which will have an insulated pipe.

Project summary

Don Valley

Don Valley plan included connecting to the Yorkshire and Humber CCS Cross-County Pipeline project. The Yorkshire and Humber project would involve the construction of a cross-country pipeline and a sub-sea pipeline to transport carbon dioxide from fossil fuel power stations and industrial plants in the region to a permanent geological storage site beneath the North Sea. Don Valley project was highlighted as a ‘follow-on load’ in the application for the project, with White Rose (a non-Network CCS project) detailed as the ‘anchor load’.

Following the announcement of the withdrawal of funding for the CCS competition in the UK, National Grid, the transport and storage proponent of the project, announced that they will be reviewing its position and holding discussions with the consortium for the White Rose project, and others in the CCS industry.¹⁵

The originally proposed CO₂ transportation infrastructure for Don Valley project includes both onshore and offshore elements (Figure 4).



Figure 3. Don Valley project location in the Yorkshire and Humber region of the UK, with the originally planned transportations system comprising of a 68 kilometre onshore. At Barmston the onshore pipeline is connected to an offshore pipeline

¹⁵ <http://www.londonstockexchange.com/exchange/news/market-news/market-news-detail/other/12597443.html>

The onshore element of the project comprises the construction of a proposed 75 km long, cross-country pipeline and associated infrastructure including pig traps, a multi-junction installation, three block valve installations and a pumping station at Barmston, South of Bridlington, near the English East coast. The proposed multi-junction installation would enable the connection of multiple pipelines from regional CO₂ sources into the common transportation system.

Multiple additional CO₂ sources close-by are being considered to utilise the pipeline capacity. Therefore, an offshore hub is planned to facilitate additional connections to alternative storage sites, including EOR in the North Sea.

ROAD

The ROAD project pipeline comprises two sections: a 5 km onshore pipeline and a 20 km offshore pipeline. Both sections employ thermal insulation on the pipe. The pipeline is capable of handling 1.1 Mtpa of CO₂ in the gaseous phase, initially captured from the ROAD Project. However, at a later stage, the flow will turn into dense phase as the back-pressure of the storage reservoir increases. The capacity of the pipeline is sufficiently large to allow CO₂ from other sources to be connected. In order to avoid the shipping lane and wind farms, the current pipeline system proposed for the ROAD project is designed to follow existing pipelines, rather than a straight line as shown on Figure 5.



Figure 4. Location of the ROAD project and its CO₂ transport lane at reclaimed land at the Rotterdam harbour

The project has considered other options for the further development of the pipeline system, such as connecting to the existing CO₂ transport system of OCAP. OCAP supplies CO₂ from the Shell Pernis refinery and from a bioethanol plant of Abengoa to greenhouses in South Holland.¹⁶ Connection of ROAD would create a functioning CO₂ hub in Rotterdam with scope for substantial additional CO₂ storage.

¹⁶ www.rotterdamclimateinitiative.com/documents/Factsheets/OCAP.pdf

Storage

Status Brief

- ✓ National Grid successfully performed drilling, coring and testing of the offshore appraisal well for Don Valley Project.
- ✓ Hontomín is at an early operational phase once the hydraulic characterization campaign has been finalized.
- ✓ The licence for the primary store of ROAD project is definitive and irrevocable, and ROAD is now considering an additional storage location.
- ✓ Gudrun field feed in on Sleipner project commenced successfully.

Summary

Safe and permanent storage of CO₂ is vital in ensuring that CCS can achieve its potential as a key climate change mitigating technology. Since the Network projects will be operational for a long time before being fully decommissioned, they are required to undergo extensive subsurface characterisation, monitoring and assurance processes.

Table 2 is the summary of the current status of the Network projects except from Sleipner (all action completed):

Table 2. Project Storage status table

	Don Valley saline	Hontomin	ROAD P18-4	ROAD Q16-Maas
Site screen	✓	✓	✓	✓
Site select	✓	✓	✓	✓
Feasibility study	✓	✓	✓	✓
Appraisal drill and/or seismic	✓	✓	n/a	n/a
Baseline surveys	□	✓	n/a	n/a
FEED	□	✓	○	○
LT monitor plan	□	✓	○	○
Storage License application	□	□	✓	n/a
CO ₂ Injectors	2-3	1	1	1
Injection backup	yes	No	no	no

○ not started □ in progress ✓ complete

Project updates

Don Valley Power Project – Saline Formation

Originally, the Don Valley Project was to capture, transport and store 4.7 Mtpa (adjusted to 1.5 Mtpa in Phase 1). This volume of CO₂ added to the 2.6 Mtpa of the planned White Rose project and other anticipated captured emissions in the region, required a sufficiently large CO₂ pipeline. Power generation and industrial output in the area is in the order of 60 Mt/year. Don Valley would be the first project to follow White Rose in benefitting from the cost savings of using a common CO₂ transport and storage infrastructure in the Yorkshire–Humber area (Yorkshire & Humber Project).

As for the Yorkshire & Humber Project (UK) itself, the formal consultation process along the proposed onshore pipeline route has been completed. An offshore survey has been conducted along the proposed pipeline route including environmental surveys and side scan sonar.

National Grid continued with developing the store, with a goal of creating a business model that would benefit other projects. Early results show that at least 100Mt of CO₂ could be injected without pressure relief. With capture from each of the White Rose and Don Valley Projects, many years of production data would have been collected before any pressure relief should be required.

Hontomín Technology Development Plant

CIUDEN continued to carry out its plans at the technology development plant. Baseline characterisation has been acquired and defined a monitoring plan according the administrative permit.

The project completed the drilling of an injection and an observation well mid-October 2013. Using percussion shallow drilling in the first one hundred meters combined with a mining rig for the deeper part, saved the Project 60% on drilling costs compared to those associated with the traditional oil sector drilling methods.

After the drilling of two wells (injection and observation), the site construction was completed. The injection and water treatment plants have been commissioned with the testing and calibration of monitoring devices.

Hydraulic characterization phase was completed from June 2014 to December 2015, achieving enough data for refining the reservoir dynamic models and to define preliminary injection strategies. For this period a total amount of 15.400 cubic meters of brine and 2.200 tons of CO₂ were injected on site as the previous stage of the early operational phase.

ROAD

The project has been granted an irrevocable storage permit for the P18-4 reservoir. The permit will need a detailed update before injection starts. As required by the CCS Directive, all plans (monitoring, corrective measures, etc.) will have to be finalized and financial security be put in place. The financial security will need to remain in place for up to 5 years after injection has stopped. It could be either an escrow deposit or a parent company guarantee. The transfer of responsibility mechanism remains an issue as elaborated in the study conducted by the project.¹⁷

¹⁷ <http://decarboni.se/sites/default/files/publications/111356/case-study-road-storage-permit.pdf>

The ROAD project is now also looking at a new storage site, Q-16 Maas, in collaboration with the operator, Oranje-Nassau Energie. The Q16-Maas condensate field is located approximately 5km from the proposed CO₂ capture plant on the ENGIE coal-fired power station. The field, operated by Orange Nassau Energie, has been producing condensates since 2014. It is located just offshore, however the production well is located onshore. Through 2015, a technical feasibility study has been conducted to explore the potential of CO₂ storage in the Q16-Maas field. It appears that altering the storage location from the P18-4 field to the Q16-Maas is technically feasible, however the latter has a much lower CO₂ capacity.

After commencement of injection, condensate production would take place simultaneously, and is expected to improve the incremental recovery of the condensate in place.

Sleipner

Operations have been underway since 1996 with demonstration of safe storage. Statoil is conducting a full storage system review. Repeated Seismic monitoring in Sleipner has allowed for significant improvements in understanding CO₂ flow dynamics. The simulation results clearly indicate that the plume beneath the caprock is gravity-dominated, and close to equilibrium at every observation point.

Policy and Regulatory Update

Status Brief

- ✓ CCS Directive review: the European Commission (EC) published a report on the review of the Directive on the geological storage of carbon dioxide (CCS Directive) in November 2015. The report finds that the Directive provides the necessary legal framework to ensure safe CO₂ capture, transport and storage while allowing Member States enough flexibility to implement it.
- ✓ Market stability reserve: The legislative proposal to create a market stability reserve was approved by the Council of the EU in October 2015. The reserve aims at addressing the current surplus of allowances and improving the system's resilience to major shocks by adjusting the supply of allowances to be auctioned, and should start in January 2019.
- ✓ EU Emission Trading System review: In July 2015 the European Commission presented a legislative proposal to revise the EU Emission Trading System (EU ETS) for the period 2021-2030. This will be discussed in the European Parliament and the Council of the European Union throughout 2016.

Timeline of key EU regulatory milestones December 2014 – December 2015:

- January 2015: a final study to the review of the CCS Directive was sent to the EC¹⁸;
- February 2015: the EC published a Framework Strategy for a resilient Energy Union with a forward-looking climate change policy¹⁹;
- July 2015: the EC issued the legislative proposal to amend the EU ETS Directive²⁰;
- October 2015: the Council of the EU formally adopted the legislative proposal to introduce a Market Stability Reserve²¹;
- November 2015: the EC published a report on the review of the CCS Directive²².

The European Commission has supported CCS with a number of policy instruments, the most important being the “CCS Directive” (Directive 2009/31/EC).

This Directive creates a framework, allowing capture and transport of CO₂ to be regulated under existing legislation and establishing a regulatory permitting regime for the storage of CO₂. It

¹⁸ Prepared by Triple E Consulting, RICARDO-AEA and TNO

¹⁹ <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2015:80:FIN>

²⁰ <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2015:337:REV1>

²¹ http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2015.264.01.0001.01.ENG

²² http://ec.europa.eu/clima/policies/strategies/progress/docs/com_2015_576_annex_2_en.pdf

establishes liability, responsibility and sets a range of obligations including storage site selection, operating, closure and monitoring activities, and the process regarding the site transfer to the relevant competent authority.

In November 2015, the EC report published on the review of the CCS Directive found that the legislation is fit for purpose and provides a regulatory framework needed to ensure safe CO₂ capture, transport and storage while allowing Member States sufficient flexibility. However, the final study, conducted by Triple E Consulting, RICARDO-AEA and TNO highlights that while being an enabling mechanism, the CCS Directive is not the main instrument driving CCS uptake and that it has had little influence on the speed of technology deployment.

Project updates

In the past year the Network projects have not received any regulatory modification and/or update. The regulatory status of the projects is as follows:

Don Valley project received funding from the European Energy Program for Recovery (EEPR). The new project developer, Sargas Power UK Limited, has been in discussions with DECC to identify a route to access a Contract for Difference to support the plant's cost of power. The project continues to benefit from the EEPR grant, and is now discussing on amending and extending the current grant agreement with the EC.

The commitment from DECC to discuss potential access to a Contract for Difference (CfD) is the next key milestone. Until that issue becomes clearer the Sargas Power team concentrates on preserving the project. National Grid's permitting of the CO₂ pipeline and appraisal of saline storage site continues with positive progress: the Development Consent Order (DCO) process is broken down into two phases. Phase 1 covers the 'trunk' pipeline from multi junction site in Camblesforth to the Barmston pumping station.

Phase 2 is the consent for the interconnecting pipeline from Don Valley to the Camblesforth Multi-junction, which also includes the compressor station.

The **ROAD project** is also in discussions with the EC about amending and extending the EEPR grant agreement. It completed basic design of the capture plant, and obtained irrevocable capture plant permits. The Engineering, Procurement and Construction (EPC) contract is ready to be signed, and the project is awaiting its final investment decision.

The **Sleipner project** is regulated under the Norwegian Act Pertaining to Petroleum Activities (under the Ministry of Petroleum and Energy) and the Pollution Control Act (under the Ministry of Environment). Building and operation of pipelines, exploration of offshore reservoirs for permanent storage, environmental impact assessment, monitoring, or third party access to pipelines or storage will fall under new regulations in the Continental Shelf Act.

The **Peterhead project** joined the EU CCS Network in November 2015. Following the UK Government funding withdrawal from the UK CCS competition, it will not proceed to further stages.²³ The project

²³ See EU CCS Network Status Report 2013-2014 for a complete description of the UK CCS Commercialisation Competition.

will honour its knowledge sharing obligations through the Front End Engineering and Design (FEED) contract with the UK Government, and will share of all key knowledge gathered so far.

CCS Directive Review

The EC conducted a review of CCS directive from May to December 2014. The review included case studies analysis, online consultation, interviews, focus groups and two stakeholder meetings. The goal of the Directive review was to see if it is fit for its purpose – if it supports CCS projects. A final study to the review of the Storage Directive was presented to the EC in January 2015, where the report concluded that:

- i) The overall need for CCS to decarbonise power production and heavy industry in Europe remains essential, even though the progress has been slow;
- ii) The Storage Directive, while being an enabling mechanism for CCS, had little influence on the pace of the technology development and it is not the main instrument driving CCS uptake;
- iii) The Directive should be revised only after more experience is gained with CCS in Europe.

Stakeholders concluded that the Directive provides a regulatory framework needed to ensure safe CO₂ capture, transport and storage while allowing the Member States sufficient flexibility. This conclusion came despite the limited information available on the Directive's practical application in Europe. Stakeholders were also concerned that reopening the Directive at this instance could be counterproductive, as it would bring a period of uncertainty for CCS, potentially harming the sector where investor confidence is already low. The Commission recognised that there is insufficient evidence at this stage to analyse potential administrative and regulatory burdens for projects not being operational in Europe yet.

Energy Union

The Commission released a Framework Strategy for a resilient Energy Union with a forward-looking climate change policy in February 2015, which builds on five key policy areas: supply security; an integrated internal energy market, energy efficiency, emissions reduction and R&D in low-carbon technologies.

The Energy Union strategy recognises CCS as an essential technology to achieve the 2050 climate objectives in a cost effective way suggesting:

“A forward-looking approach to carbon capture and storage (CCS) and carbon capture and use (CCU) for the power and industrial sectors, which will be critical to reaching the 2050 climate objectives in a cost-effective way. This will require an enabling policy framework, including a reform of the Emissions Trading System and the new Innovation Fund, to increase business and investor clarity, which is needed to further develop this technology.”²⁴

EU Emission Trading System

The EU ETS is a cornerstone of the EU's climate policy and a key mechanism for reducing industrial CO₂ emissions. The scheme works on a 'cap and trade' basis: there is a 'cap' or limit set on the total greenhouse gas emissions allowed to all participants covered by the System and this cap is converted

²⁴ <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2015:80:FIN>

into tradable emission allowances. Tradable emission allowances are allocated to participants in the market via a mixture of free allocation and auctions. One allowance gives the holder a right to emit one tonne of CO₂ (or its equivalent). Participants covered by the EU ETS must monitor and report their emissions each year and surrender enough emission allowances to cover their annual emissions.

Market Stability Reserve

The European institutions designed a structural reform of the EU ETS in order to address low market price of allowances. The EC's legislation proposal to introduce a Market Stability Reserve (MSR) was endorsed by the European Parliament in July 2015 and formally adopted by the Council in October 2015. The MSR will operate entirely according to pre-defined rules that leave no discretion to the Commission or Member States on its implementation. The legislation rules that the reserve should start operating from January 2019: 900 million allowances are to be placed in the reserve instead of returning to the market in the period 2019-2020.

EU ETS Directive revision

In July 2015 the European Commission issued a legislative proposal to revise the EU ETS Directive for the period 2020-2030. The purpose of the proposal is to:

- i) Update the system free allocation to focus on sectors at highest risk of relocating their production outside the EU (carbon leakage);
- ii) Set aside free allowances for new and growing installations;
- iii) Design more flexible rules to better align the amount of free allowances with production figures;
- iv) Update the EU benchmarks to reflect technological progress;
- v) Establish support mechanisms to help the transition of Member States to a low-carbon economy (Innovation Fund).

Innovation Fund

The Innovation Fund is a support mechanism meant to finance, through the sale of 450 million emission allowances, demonstration projects of innovative renewable energy technologies, carbon capture and storage and low-carbon innovation in industrial sectors. The Innovation Fund (aka NER400) extends the support provided to low-carbon technologies by its predecessor, NER300, as it applies also to industrial carbon abatement technologies. As NER400 is to start only in 2020, the EC has allocated proceedings from 50 million allowances towards low-carbon innovation projects before 2020. These additional allowances could be monetised as of January 2019, thus partially reducing the funding gap between the two NER programmes. The Innovation Fund structure has still to be outlined as it is currently under consideration in the European Parliament and the Council.

Outreach and Global Knowledge Sharing

The deployment of CCS can benefit from knowledge-sharing on a global level. This is why the Secretariat, in collaboration with the US Department of Energy (DOE) organized the first international Knowledge Sharing Forum in Houston, Texas. The participating projects were: Boundary Dam Project (Canada); Don Valley Project (UK); Illinois Industrial Project (U.S.); Peterhead Project (UK); Petra Nova Project (US); ROAD Project (the Netherlands); Sinopec Shengli Project (China); and Texas Clean Energy Project (U.S.).

This Knowledge-Sharing Forum focused on identifying best practices in project development; exchanging experience complying in different regulatory environments; and examining effective financial supporting mechanisms. Following general presentation of projects and their latest developments, the group discussed:

1. Business models and financing of CCS projects session;
2. Technical session on capture and transport;
3. Session on public perception;
4. Technical session on CO₂ storage.

Participants gave positive feedback on the event, as sessions organized in small groups allowed a high quality of discussions and a focus on specific project details through effective interactions. The projects found useful to learn about CCS developments in other regional areas and to understand drivers for projects that are to operate in different markets.

In the past year, the Network Secretariat also participated in numerous public events to ensure effective dissemination of the Network activities. Projects' experiences are leveraged by engaging not only with the CCS community, but also with broader energy and climate change platforms, as this is crucial in building public confidence about the necessity, feasibility and safety of CCS.

Conclusion

The European CCS Demonstration Project Network is a unique collaboration of projects, covering the main capture technologies in the power sector, a range of transport options, and a variety of on- and off shore storage sites. It has shown a strong commitment to knowledge and experiences sharing on CCS, as these are crucial for the wide deployment of this low-carbon technology.

In 2015 the Network was comprised of an Integrated Pressurized Capture Technology power project (Don Valley), two post-combustion power projects (Peterhead and ROAD), a gas processing project (Sleipner), and former Compostilla project which was planning to demonstrate oxy fuel combustion. All of the Network projects have a detailed understanding of the technologies they have chosen and have been able to provide detailed data for the systems. Each and every project plans to capture over 1 million tonnes of CO₂ per annum, at a capture rate of over 90% once in operation.

Sleipner is the only project currently in operation. The Network projects' works towards operational status continue to be developed, despite delays mainly due to difficulties in making final investment decisions.

Two of the Network's projects, Compostilla and Peterhead, will not be proceeding to large scale demonstration, due to market changes and weak policy support. The Compostilla project stays in a "collaborative" status, while the Peterhead project is committed to share the knowledge acquired during FEED studies. The Don Valley project is working towards receiving a positive FID provided that the UK government makes Contracts for Difference (CfDs) available to CCS projects. ROAD project has acquired all of the permits required and is now awaiting for an FID.

There are two main reasons for the overall deployment delay of projects – (i) policy uncertainty and (ii) funding challenges. A good example how policy uncertainty adversely impacts projects is the UK Government's announcement to withdraw the funding from the UK CCS competition, resulting in cancellation of the Peterhead project. The decision of the UK Treasury to cancel the £1 billion competition came six months before the funding was due to be disbursed to successful projects. As such, companies' confidence to financially commit to CCS has been undermined. Like other large-scale technology projects, CCS has large capital costs and development times, thus investors require long-term certainty that they can invest in CCS.

Policy uncertainty and funding challenges in Europe are still preventing the wide scale deployment of CCS, threatening to greatly increase the cost of the future decarbonisation of the European economy and hampering the achievement of the EU climate mitigation targets.

Appendix 1 - Glossary

CCS	Carbon capture and storage
CCS Directive	European Directive 2009/31/EC on the geological storage of carbon dioxide
CfD	Contract for differences
CO₂	Carbon dioxide
DECC	Department of Energy and Climate (UK)
EC	European Commission
EEPR	European Energy Programme for Recovery
EOR	Enhanced oil recovery
ETS	European Directive 2009/29/EC on the greenhouse gas emission allowance trading scheme of the Community
EU	European Union
EUA	European Union Allowances - 1 EUA represents the right to emit 1 tonne of CO ₂
FEED	Front end engineering design
FID	Final investment decision
GHG	Greenhouse gas
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
km	Kilometre
kW	Kilowatt
MMV	Monitoring, measurement and verification
MVA	Monitoring, verification and accounting
Mtpa	Million tonnes per annum; million tonnes a year
MW	Megawatt
MWe	Megawatts electrical capacity
MWth	Megawatt thermal
NER300	New Entrants' Reserve 300
NER400	New Entrants' Reserve 400 – Innovation Fund
NGCC	Natural gas combined cycle
NGO	Non-government organisation
NOx	Nitrogen oxides
R&D	Research and Development
RD&D	Research, Development and Deployment
SOx	Sulphur oxides

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The European CCS Demonstration Project Network was established in 2009 by the European Commission to accelerate the deployment of safe, large-scale and commercially viable CCS projects. To achieve this goal, this community of leading demonstration projects is committed to sharing knowledge and experiences. The successful deployment of this key technology will allow Europe to reach its environmental objectives, stimulate job creation, and generate a sustainable economic and industrial base.

Network support provided by:

