Project no.: 256725

Project acronym: CGS Europe

Project title: Pan-European Coordination Action on CO_2 Geological Storage

Instrument: Coordination and Support Action

Thematic Priority: SP1-Cooperation, FP7-ENERGY-2010-1

D4.10 Joint Research Activities. Report 3 [Year 2]

Due date of deliverable: 31/03/2013
Actual submission date: 29/09/2013

Start date of project: 1st November 2010 Duration: 36 months

Instituto Geológico y Minero de España (S-IGME)

Version: Final Document

Project co-funded by the European Commission within the Seventh Framework Programme
Dissemination Level * : PU

* select one of the following
PU = Public
PP = Restricted to other programme participants (including the Commission Services).
RE = Restricted to a group specified by the consortium (including the Commission Services).
CO = Confidential, only for members of the consortium (including the Commission Services).
Make sure that you use the correct following label when your project has classified deliverables.
EU restricted = Classified with the mention of the classification level restricted "EU Restricted"
EU confidential = Classified with the mention of the classification level confidential " EU Confidential "
EU secret = Classified with the mention of the classification level secret "EU Secret "

CGS EUROPE REPORT ON JOINT RESEARCH ACTIVITIES

1. Objectives

CGS Europe is a Pan European action and one of its main goals is to widespread CCS technologies and related activities within all participant countries. CGS Europe partners are mainly scientific organizations, but there are also national authorities and technology appliers. In that situation, to reach that goal, CGS Europe programmed an entire Work Package (WP4) dedicated to "Knowledge Development", including a specific task that aims at helping the partners to (at least) partially align their research programmes. Other tasks in WP4 also contribute to share knowledge and experiences through workshops and staff exchanges.

In this sense, both the Advisory Body and mid-term reviewers from the EC have supported the idea to create strong links between CGS Europe and other active bodies related to geological storage of CO_2. In the last reporting period, CGS Europe has strongly cooperated with the Zero Emission Platform (ZEP) in order to promote CO_2 storage pilot projects in Europe, dedicating large efforts to the creation of a common report between the two bodies. This action will be completed in the next period and was largely supported during the 8th CO2GeoNet Open Forum held in April 2013 and focused on storage pilots.

Another relevant activity has been the cooperation to promote transposition of EU Directive on Geological Storage of Carbon Dioxide and further legislation. In this issue, an article about the status of the process written by a large number of project partners was presented at the GHGT-11 Congress in Kyoto. A more detailed article including case studies has been reviewed by SCI publications, although not accepted for publication at the moment.

.

2. CGS Europe and ZEP common report on storage pilot projects

2.1 Introduction

The European Zero Emissions Platform (ZEP) Task Force on Technology has created a Working Group on CO_2 Storage Infrastructures in order to promote R&D and industrial activities that will drive to a wide deployment of CCS technologies in Europe. This Working Group agreed to give priority to the implementation of CO_2 storage Pilot and Demonstration Projects, in order to add knowledge, safety and reliability to already active initiatives. At this point, ZEP and CGS Europe agreed to actively cooperate in this WG, through the exchange of information, local knowledge and project proposals.

It was considered very interesting to give all CGS Europe partners the possibility to give information about potential CO_2 storage pilots to be held in their home countries or surrounding regions. Therefore, a questionnaire was generated in order to be submitted to project partners and ZEP WG participants, seeking a Pan European set of information that may lead to new pilot projects. ZEP will seek EC support to, at least, some of the proposed projects.

The are several motivations to support the design and deployment of CO_2 storage pilot projects, but mainly they are aimed to obtain better, cheaper and more precise technologies related to exploration, injection, monitoring, completion of wells, etc. They are necessary to keep research on going, accompanying demonstration and industrial deployment. In this sense, these demonstrations will be more successful if they can use best available technologies once they have been tested at a pilot scale. Storage pilots are also an excellent opportunity to demonstrate to the public the feasibility and safety of storage and to experience a dialogue approach with the civil society.

2.2 Questionnaire

The first step that was taken in the development of this work was to elaborate a questionnaire, seeking two main characteristics:

1. **Simplicity**, in order to facilitate answers in a way that the participant that is filling it finds easy to give relevant information not wasting time in the format.
2. **Precision,** having the goal to obtain clear information about key factors that define the potentiality of each proposal. Knowing that the availability of data is very different in each country, deviations have to be mitigated through the format.

Therefore, the Working Group of ZEP in Storage Infrastructures, together with the CGS Europe WP4 team, made efforts in the generation of a questionnaire that would have both qualities. In this first stage, a first draft was proposed by WG coordinators and discussed by electronic mail between members.

Some key aspects were taken in account when defining the questionnaire. These aspects are related to different fields of knowledge and information, such as physical description, potential consortium, possibilities for upgrading or sociopolitical issues. It was finally agreed to fill up the following fields:

COUNTRY: Storage site location. If other countries involved, please indicate them also
TYPE OF STORAGE: Saline aquifer, depleted oil field, depleted gas field, EOR…
LOCATION: Onshore or Offshore
STORAGE FORMATION LITHOLOGY: Rock classification (sandstone, limestone, dolostone…)
SEALING FORMATION LITHOLOGY: Rock classification of primary seal (clay, marl, chalk…)
STORAGE REQUIREMENT: Estimated CO_2 (Kt) to be injected and stored in the Pilot.
STORAGE CAPACITY: Estimated storage capacity (Mt) of the proposed site (Please provide how it was estimated: screening formulae, dynamic simulation…) Can the pilot project be upgraded to demonstration or industrial storage site?
POTENTIAL R&D CONSORTIUM: Indicating potential industrial and research consortium, taking in account that it will be positively evaluated a wide implication of research institutions. Who will supply the CO_2?
CLOSE EMISSION SOURCES: Including only relevant CO_2 emitters in the surroundings of the proposed pilot. Are they potential users of the data for demonstration projects?
PROJECT BUDGET: Just a very rough estimation of investment needed and operation costs is needed.
POTENTIAL COMBINATION WITH CAPTURE PROJECTS: Are there plans to build capture projects in the country? And, in the surroundings of the proposed pilot?
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES: Only positive answer if there is an interest on geothermal uses in the area of the proposed pilot.
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE: Only positive answer if biomass combustion is planned in the neighbouring emitters.
POTENTIAL COMBINATION WITH CO2 USES: Only positive answer if there is an interest on CO_2 alternative uses (algae, greenhouses, industry…) in the area of the proposed pilot.
STATE SUPPORT: Does the National and/or Local Administration support CO_2 storage. Is it expected to receive funding from these Administrations?
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES: Please indicate if there is a particular interest for a pilot in the region, because of employment, coal production, industrial history, etc.
COMMENTS: Any other interesting data

Answers were gathered from many CGS Europe partners, although in some cases they advised about the lack of pilot project possibilities in their countries. But many of the answers were positive and more than 20 project proposals could be analysed. Final results will be discussed in a report that will be released in the following months. In any case, it has to be stated that large efforts were made by partners in order to polish their proposals and adapt them to changes and situations that took place along the year of reporting.

2.3 Main conclusions

Answers collected from CGS Europe partners prove that options for pilot project development are widely distributed across Europe and the scientific community is ready to provide these ideas to the industry and to the national and European authorities in order to develop this kind of projects. This report presents several options in each different type of storage formation (saline aquifers, active hydrocarbon fields, depleted hydrocarbon fields), making therefore available the improvement of technologies under different conditions. We need to remark that each storage site is unique and therefore needs specific exploration, operation and monitoring plans. Pilot scale projects will be open research platforms to allow field experiments that will supply very relevant information for future design of such plans.

Diversity in the options is also available from the point of view of the geological setting. Examples are provided in sandstones, sands and carbonated rocks, sealed by clays, shales or marls, rocks where CO_2 behaviour is expected to be quite different from one to the other. Although most of the proposals are located onshore, providing examples closer to the affected communities, there are also offshore proposals.

The geographical distribution of the proposals is well balanced at the European level, as proposals have been submitted from a significant number of countries, both from the North and the South, from the East and the West. In CGS Europe opinion, it is desirable that this geographical distribution is maintained when deploying real projects. In any case, results need to be integrated, perhaps by including pilot scale projects into the EU CCS Project Network, which is up to now devoted to Demonstration projects only.

CGS Europe partners have reported a general lack of funding schemes to develop these projects. In this aspect, ZEP report “Accelerating the demonstration of CO_2 geological storage in Europe”, provides a good starting point to study combined options for funding in absence of a viable business model for geological storage at the present moment. Engagement of research programmes, national and regional funding, industry and other associated revenues may provide an adequate framework for these projects. Average budgets are from 20 to 50 M€ but expected added value is quite larger than that. Some of the consortia that have been proposed by CGS Europe partners already include actors from the scientific community, but also from different sectors of the industry, in some cases supported by national and local authorities. To keep progressing in this field is crucial for pilot project deployment and, therefore, for the technology itself. Moreover, the experience gathered in these projects will increase confidence in tackling new situations when demonstrations are deployed.

Finally, because of the amount, diversity and quality of the answers that have been provided to this report (see table 1), it can be concluded that CGS Europe – CO_2GeoNet, as an independent and durable scientific body that deals with all aspects of CO_2 storage, is in a very good position to help in the coordination of pilot projects, in the creation of links between them, in integrating research and results and in transferring newly acquired knowledge to the industrial sectors and the society as a whole.

Table 1 Summary of Pilot Project Proposals

COUNTRY	PILOT NAME	LOCATION (ON/OFF)	TYPE	DEPTH (m)	LITHOLOGY	FORECASTED BUDGET (M€)
Bulgaria	Pavlikeni	Onshore	Aquifer	800 - 1400	Limestone	
Czech Republic	Czech Republic	Onshore	EOR/Oil field	1600	Sandstones	20 - 40
Denmark	Skagerrak	Onshore	Aquifer	1200 - 1500	Sandstones	
France	Paris Basin	Onshore	Aquifer	2500 - 3000	Sandstones	55
Hungary	Hungary	Onshore	Aquifer	1500	Sandstones	20
The Netherlands	Q01	Offshore	Aquifer	1300 - 1600	Sandstones	50
The Netherlands	K12-B	Offshore	Gas field	3000	Sandstones	30 - 100
The Netherlands	Rotterdam	Onshore	Gas field (seasonal)	1200 - 1600	Sandstones	40
Norway	Sleipner	Offshore	Aquifer	750 - 900	Sandstones	
Norway	Snøhvit	Offshore	Aquifer	2430	Sandstones	
Norway	Svalbard	Onshore	Aquifer	670 - 970	Sandstones	
Norway	Svelvik	Onshore	Field lab	20 - 100	Sands	
Norway	Mongstad	Offshore				Large
Poland	Dziwie	Onshore	Aquifer	1250	Sandstones	19
Portugal	Lusitania	Onshore	Aquifer	1600	Sandstones	5
Romania	Turceni	Onshore	EOR	2200	Sandstones	20 - 40
Romania	Rovinari	Onshore	Aquifer	1400	Sands	20 - 40
Romania	Craiova	Onshore	Oil field	1500	Sandstones	20 - 40
Romania	Galati	Onshore	Oil field	2000	Sands	20 - 40
Slovakia	Vienna	Onshore	Oil & gas field	1350 - 1450	Limestone	9
Slovakia	Ptruksa	Onshore	Gas field	1450-1850	Sandstones	9
Slovakia	Stretava	Onshore	Gas field	1100 - 1700	Sandstones	8
Slovakia	Marcelová	Onshore	Aquifer	1000-1700	Carbonates	25
Spain	Hontomín	Onshore	Aquifer	1600	Limestone	30
Turkey		Onshore	EOR			
United Kingdom	UK on	Onshore	Aquifer	800 - 1200	Sandstones	
United Kingdom	UK off	Offshore	Field lab	12	Sediment	2

3. Activities on EU Directive transposition

The first knowledge sharing workshop organized by CGS Europe in Venice in May 2011 treated different issues related to the status of the process of transposition of the EU Directive on geological storage of carbon dioxide to national legislations. This workshop was very successful both in the quality of presentations and in the number of attendees, who confirmed the conclusion obtained in the questionnaire described above, promoting further participation of research institutions in the regulation process.

A large group of CGS Europe partners prepared an abstract of an article about regulation issues at a European level that was presented in Deliverable 4.9. This abstract was sent to the organization of the 11th Conference on Greenhouse Gases Technologies (GHGT-11) and was accepted for oral presentation. A full paper was submitted and it was presented by Sam Holloway (BGS-CO_2GeoNet) at GHGT-11 in Kyoto, Japan on November 2012.

Moreover, a more detailed article including case studies in different Member States was prepared in order to be sent to the International Journal on Climate Change, seeking impact in the scientific community, in order to involve researchers in the elaboration and monitoring of new laws. Unfortunately, the IJGGC rejected the article and other options are being managed for publication.

4. Forthcoming actions

In the last months of CGS Europe project, two main actions will centre the action of Task 4.1:

- Final release of the storage pilot project proposals (incl. Executive Summary)
- Final mapping of CGS Europe countries status on CO_2 storage research and implementation

Both actions will generate reports that will be available for the public and will help to understand the situation of CGS in Europe and the potentialities of development in all participant countries.

Moreover, in the last year of the project, WP4 will include a new action for joint knowledge sharing. This is an educational course on CO_2 storage that will be held in Athens, devoted to new CCS teams in CGS Europe partners.

ANNEX I

QUESTIONNAIRES ON CO_2 STORAGE PILOT PROJECTS AS FILLED BY CGS EUROPE PARTNERS
(by country in alphabetic order)

PAVLIKENI	
COUNTRY	Bulgaria
TYPE OF STORAGE	Saline aquifer
LOCATION (ON/OFF)	Onshore
DEPTH TO TOP OF STORAGE FM	800 - 1400
STORAGE FORMATION LITHOLOGY	Carbonates (limestone & dolomites
SEALING FORMATION LITHOLOGY	marl
STORAGE REQUIREMENT (PILOT)	
ESTIMATED STORAGE CAPACITY	460 Mt – estimated by screening formulae. Can the pilot project be upgraded to demonstration or industrial storage site? – I think yes
POTENTIAL R&D CONSORTIUM	
CLOSE EMISSION SOURCES	Maritsa East power plants
PROJECT BUDGET	
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	Yes
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	No
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	No
POTENTIAL COMBINATION WITH CO2 USES	
STATE SUPPORT	
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	
COMMENTS	

NAME OF SITE	
COUNTRY	Czech republic (potential involvement of Slovakia regarding CO_2 source)
TYPE OF STORAGE	EOR / depleted oilfield
LOCATION (ON/OFF)	onshore
DEPTH TO TOP OF STORAGE FM	ca 1600 m
STORAGE FORMATION LITHOLOGY	sandstone
SEALING FORMATION LITHOLOGY	claystone
STORAGE REQUIREMENT (PILOT)	20 – 40 kt
ESTIMATED STORAGE CAPACITY	0.6 Mt – result of simplistic modeling by IFP within EU GeoCapacity; the pilot can be upgraded to small demo, also including other blocks of the same oilfield
POTENTIAL R&D CONSORTIUM	Czech Geological Survey, local oil company (tbc), IRIS Stavanger, Technical University Ostrava, NRI Řež, potentially further CGS Europe partners. CO2 supply tbd
CLOSE EMMISSION SOURCES	Hodonin power plant (10 km), Duslo Šala chemical factory (Slovakia, producer of highly concentrated CO2 stream, 100 km distance)
PROJECT BUDGET	20-40 M€ (ca 5 M€ for the preparatory stage)
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	No plans at the moment; potential for low-cost capture exists at Duslo Šala (Slovakia)
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	no
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	Biomass is co-fired at the Hodonin power plant
POTENTIAL COMBINATION WITH CO2 USES	CO_2EOR
STATE SUPPORT	Support can be expected from Norway Grants for the preparatory stage
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	There is interest to prolong the life of the oilfields in the region, incl. their further use
COMMENTS	The project is in its very initial stage

NAME OF SITE	
COUNTRY	Storage in Denmark, with project partners from Denmark, Norway and Sweden
TYPE OF STORAGE	Research pilot
LOCATION (ON/OFF)	Northern Jutland, precise location not selected yet. It will be on shore.
DEPTH TO TOP OF STORAGE FM	Around 1200-1500 m
STORAGE FORMATION LITHOLOGY	Gassum Formation Sandstone
SEALING FORMATION LITHOLOGY	Fjerritslev Formation, shales (secondary sealing formations: Børglum Formation, shales, Chalk Group, carbonates)
STORAGE REQUIREMENT (PILOT)	Research pilot borehole
ESTIMATED STORAGE CAPACITY	Large (several MT CO_2)
POTENTIAL R&D CONSORTIUM	**"CO2 Injection Pilot Skagerrak:"** GEUS, Tel-Tek and University of Oslo (UiO), Lund University? Industry partner: Statoil, EON?, Gassnova SF, Vattenfall Supply of CO_2 will not be desided until we know the amounts, but Yara or TCM are options that wil be considered.
CLOSE EMMISSION SOURCES	There are several local point sources in the Skagerrak area located in larger cities within a 100 km circle covering Denmark, Norway and Sweden (Aalborg, Oslo, Grenland, Gothenburg (e.g. Nordjyllandsværket (Aalborg power plant), Aalborg-Portland cement factory) refinery, petrochemical (Gothenburg) (Gothenburg) Norcem cement factory (Grenland), Esso Slagentangen (Refinery), Yara chemical plant (Grenland) and industry in Oslo)
PROJECT BUDGET	In planning phase
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	Not planned yet
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	Yes (Aabybro Fjernvarmeværk, Hjørring Fjernvarme, and others)
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	No
POTENTIAL COMBINATION WITH CO2 USES	No
STATE SUPPORT	Not likely The project will send an application to Gassnova in Norway.
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	New crucial data and information on the properties of the Gassum Formation. Necessary for further planning of CO_2 offshore storage in the Skagerrak area, and very valuable information for local geothermal projects in Denmark
COMMENTS	The main purpose of the project is to assess if the Gassum Formation is suitable for CO_2 storage through a series of analyses including reservoir evaluation based on well-log interpretations, core descriptions, flow and injection tests, full core injection tests, poro-perm measurements on closely spaced core plucks, microscope work on mineralogy and cement etc. An on-going feasibility study will conduct a pre-screening and rank the sites where injectivity tests can be performed. The feasibility study will also do a first assessment of logistics and safety issues related to testing, as well as of infrastructure, management of CO_2 injection and monitoring. Detailed planning of the injection tests, with all technical, cost and practical challenges will be addressed. The feasibility study is to be finished in October 2012. The operational part of the injection will require dialogue with industry partners and stakeholders. Injection of water can give valuable information about the porosity and permeability of the formation. The use of CO_2 as injection fluid is probably necessary for adequate evaluation and testing of all important aspects of CO_2 storage, logistics etc. tied to future use of the Gassum Formation.

NAME OF SITE: Paris Basin	
COUNTRY	France
TYPE OF STORAGE	Saline aquifer
LOCATION (ON/OFF)	Onshore
DEPTH TO TOP OF STORAGE FM	Between 2500 and 3000 m
STORAGE FORMATION LITHOLOGY	Sandstones and siltstones (Keuper)
SEALING FORMATION LITHOLOGY	Clays (Upper Triassic, and Liassic)
STORAGE REQUIREMENT (PILOT)	10 Kt CO2 phase 1 90 Kt CO2 phase 2
ESTIMATED STORAGE CAPACITY	100 Mt CO2
POTENTIAL R&D CONSORTIUM	BRGM, IFPEN, Universities, Geodenergies*, CO2GeoNet**, + a supplier of the CO2 * New research institute with 35 public and private partners (see list of partners on next page) ** European Network of Excellence on CO2 geological storage – current membership of the Association is 13 research institutes from 7 countries
CLOSE EMMISSION SOURCES	Industrial or bio-fuel plant or biomass heat plant for the pilot stage Le Havre or Lorraine power & industrial plants if later upgraded to demonstration and industrial storage site
PROJECT BUDGET	55 M€ (including two wells)
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	Capture at biofuel plant (adaptation of the fermentation unit for ensuring high purity CO2 (>95%)) or at biomass heat plant or at industrial plants (source mutualisation)
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	Yes. A new research project CO2-DISSOLVED has just been selected for funding by ANR, the French National Agency for Research –started in January 2013 (storage as dissolved CO2, combined with brine production – injection & production doublet)
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	YES! This can be an option for this pilot if final location is sited nearby the biofuel production spot of Seine valley or Region Centre. A research project in this latter geographical area co-funded by Region Centre (project CPER ARTENAY) was presented at the 1st International Bio-CCS Conference held in Orleans in 2011.
POTENTIAL COMBINATION WITH CO2 USES	No
STATE SUPPORT	National administration supports CO2 storage. Early discussions have been initiated with potential funding bodies: ADEME (National Agency of Energy and Environment), ANR (National Agency for Research), MESR (Ministry of Research and Higher Education).
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	Reduction of industrial CO2 emissions, development of renewable energies, sustainable development. Research and training platform that will benefit both the regional and national activities and will have an international outreach.
COMMENTS	Pilot project in a very early stage of design. Follows previous feasibility project for a CO2 storage research demonstrator in the envisaged area, and previous CO2 storage and geothermal research projects targeting the same Triassic reservoir, These previous projects were supported by ADEME, Region Centre, FEDER, etc.

NAME OF SITE	
COUNTRY	HUNGARY
TYPE OF STORAGE	saline aquifer
LOCATION (ON/OFF)	Onshore
DEPTH TO TOP OF STORAGE FM	>1500m
STORAGE FORMATION LITHOLOGY	sandstone
SEALING FORMATION LITHOLOGY	clay/marl
STORAGE REQUIREMENT (PILOT)	30 000 – 10 000/y
ESTIMATED STORAGE CAPACITY	>1 Mt /volumetric estimation/ can be upgraded to industrial storage site
POTENTIAL R&D CONSORTIUM	MOL Plc, ALSTOM, Others
CLOSE EMMISSION SOURCES	biomass/biogas plants, partial flue-gas stream of gas fired powerplants
PROJECT BUDGET	> 20 M€
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	no
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	potentially
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	probable
POTENTIAL COMBINATION WITH CO2 USES	not foreseen
STATE SUPPORT	probable
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	employment options, renewed transport and communication infrastructure, trainings
COMMENTS	

NAME OF SITE: Offshore saline aquifer Q01	
COUNTRY	Netherlands
TYPE OF STORAGE	Saline aquifer
LOCATION (ON/OFF)	offshore
DEPTH TO TOP OF STORAGE FM	1300-1600m
STORAGE FORMATION LITHOLOGY	Vlieland Sandstone (Early Cretaceous)
SEALING FORMATION LITHOLOGY	Vlieland Claystone
STORAGE REQUIREMENT (PILOT)	No particular requirement, injection test of <100 kT
ESTIMATED STORAGE CAPACITY	~114 Mt
POTENTIAL R&D CONSORTIUM	TNO, CATO (Dutch CCS program), Rotterdam Climate Initiative (RCI), …
CLOSE EMMISSION SOURCES	CO2 from Rotterdam area (CO2-hub)
PROJECT BUDGET	Estimated at ~50 M€
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	CO2 capture from Rotterdam area (CO2-hub)
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	
POTENTIAL COMBINATION WITH CO2 USES	
STATE SUPPORT	Under consideration depending on follow-up of CATO2 program
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	Offshore site, no direct consequences for local community
COMMENTS	Large capacity aquifer with low pressure (lower than hydrostatic pressure) due to hydrocarbon production from local structures

NAME OF SITE: Transport by shipping to K12-B	
COUNTRY	Netherlands
TYPE OF STORAGE	Depleted gasfield
LOCATION (ON/OFF)	offshore
DEPTH TO TOP OF STORAGE FM	>3000m
STORAGE FORMATION LITHOLOGY	Rotliegend sandstone
SEALING FORMATION LITHOLOGY	Zechstein salt
STORAGE REQUIREMENT (PILOT)	No particular requirement, already >70kt has been injected
ESTIMATED STORAGE CAPACITY	~25 Mt
POTENTIAL R&D CONSORTIUM	TNO, CATO, GDF-SUEZ (depending on the terms & conditions)
CLOSE EMMISSION SOURCES	CO2 from natural gas production, shipping from the Rotterdam harbour
PROJECT BUDGET	Estimated at ~30-100 M€
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	Integrated pilot test of transport by shipping from Rotterdam area (CO2-hub) and injection from the ship in the reservoir
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	
POTENTIAL COMBINATION WITH CO2 USES	Potential for EGR
STATE SUPPORT	Under consideration depending on follow-up of CATO2 program
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	Offshore site, no direct consequences for local community
COMMENTS	Continuation of the current demo project with shipping transport as a specific topic of research.

NAME OF SITE: Seasonal storage in small depleted/undeveloped gasfields	
COUNTRY	Netherlands
TYPE OF STORAGE	Seasonal storage in small depleted/undeveloped gasfields (several potential fields in the Rotterdam area)
LOCATION (ON/OFF)	onshore
DEPTH TO TOP OF STORAGE FM	~1200-1600m
STORAGE FORMATION LITHOLOGY	Early Cretaceous sandstone reservoirs
SEALING FORMATION LITHOLOGY	Claystone
STORAGE REQUIREMENT (PILOT)	~10-100 kT
ESTIMATED STORAGE CAPACITY	Unknown
POTENTIAL R&D CONSORTIUM	TNO, CATO (Dutch CCS program), Rotterdam Climate Initiative (RCI), …
CLOSE EMMISSION SOURCES	CO2 from Rotterdam area (CO2 hub)
PROJECT BUDGET	Estimated at ~40 M€
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	
POTENTIAL COMBINATION WITH CO2 USES	CO2 buffer reservoir for greenhouses, that require CO2 seasonally, link to the existing CO2 OCAP-pipeline
STATE SUPPORT	Under consideration depending on follow-up of CATO2 program
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	Use of reservoir as a buffer for greenhouses in the area
COMMENTS	The project is meant to investigate the potential for small fields to be developed by using them for CO2 buffer storage. The potential for geothermal use will also be evaluated. The seasonal storage allows to study in detail the behaviour of reservoirs within multiple cycles of injection and production.

Sleipner	
COUNTRY	Norway
TYPE OF STORAGE	Saline aquifer
LOCATION (ON/OFF)	Offshore
DEPTH TO TOP OF STORAGE FM	750-900 m
STORAGE FORMATION LITHOLOGY	Utsira sandstone
SEALING FORMATION LITHOLOGY	Mudstone (Nordland group)
STORAGE REQUIREMENT (PILOT)	na
ESTIMATED STORAGE CAPACITY	14 Mt injected and counting
POTENTIAL R&D CONSORTIUM	
CLOSE EMMISSION SOURCES	Oil-and gas streams
PROJECT BUDGET	n.a.
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	From gas processing offshore
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	Only with a low efficiency, and only very few users out there.
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	no
POTENTIAL COMBINATION WITH CO2 USES	Potential EOR pilot tests
STATE SUPPORT	indirect
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	no
COMMENTS	

Snøhvit	
COUNTRY	Norway
TYPE OF STORAGE	Saline aquifer
LOCATION (ON/OFF)	offshore
DEPTH TO TOP OF STORAGE FM	Ca 2430 m
STORAGE FORMATION LITHOLOGY	Tubåen sandstone
SEALING FORMATION LITHOLOGY	
STORAGE REQUIREMENT (PILOT)	n.a.
ESTIMATED STORAGE CAPACITY	1 Mt injected and counting
POTENTIAL R&D CONSORTIUM	
CLOSE EMMISSION SOURCES	no
PROJECT BUDGET	
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	Oil and gas streams
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	no
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	no
POTENTIAL COMBINATION WITH CO2 USES	Potential EOR pilots
STATE SUPPORT	indirect
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	no

Longyearbyen CO2 Laboratory	
COUNTRY	Norway
TYPE OF STORAGE	Saline aquifer
LOCATION (ON/OFF)	Svalbard / onshore
DEPTH TO TOP OF STORAGE FM	670 – 970 m
STORAGE FORMATION LITHOLOGY	Sandstone
SEALING FORMATION LITHOLOGY	shale
STORAGE REQUIREMENT (PILOT)	Field laboratory
ESTIMATED STORAGE CAPACITY	Small
POTENTIAL R&D CONSORTIUM	
CLOSE EMMISSION SOURCES	Coal power plant
PROJECT BUDGET	
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	Coal power plant
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	no
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	no
POTENTIAL COMBINATION WITH CO2 USES	
STATE SUPPORT	yes
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	

Svelvik	
COUNTRY	Norway
TYPE OF STORAGE	Field laboratory (leakage)
LOCATION (ON/OFF)	onshore
DEPTH TO TOP OF STORAGE FM	20 – 100 m
STORAGE FORMATION LITHOLOGY	Unconsolidated sand
SEALING FORMATION LITHOLOGY	No seal
STORAGE REQUIREMENT (PILOT)	No more than 200 tons
ESTIMATED STORAGE CAPACITY	No capacity, minor amounts for field testing
POTENTIAL R&D CONSORTIUM	
CLOSE EMMISSION SOURCES	no
PROJECT BUDGET	
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	no
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	no
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	no
POTENTIAL COMBINATION WITH CO2 USES	no
STATE SUPPORT	yes
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	no

MONGSTAD	
TYPE OF STORAGE	Capture plant, exploration for storage site ongoing
LOCATION (ON/OFF)	offshore
DEPTH TO TOP OF STORAGE FM	
STORAGE FORMATION LITHOLOGY	
SEALING FORMATION LITHOLOGY	
STORAGE REQUIREMENT (PILOT)	pilot
ESTIMATED STORAGE CAPACITY	
POTENTIAL R&D CONSORTIUM	
CLOSE EMMISSION SOURCES	Yes, the Mongstad power plant
PROJECT BUDGET	Huge?
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	Yes, the Mongstad power plant
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	no
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	no
POTENTIAL COMBINATION WITH CO2 USES	Potentially EOR tests?
STATE SUPPORT	yes
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	no

NAME OF SITE - DZIWIE	
COUNTRY	POLAND
TYPE OF STORAGE	SALINE AQUIFER
LOCATION (ON/OFF)	ONSHORE
DEPTH TO TOP OF STORAGE FM	1250
STORAGE FORMATION LITHOLOGY	sandstone
SEALING FORMATION LITHOLOGY	claystone, mudstone
STORAGE REQUIREMENT (PILOT)	27 kt
ESTIMATED STORAGE CAPACITY	~1 Mt static capacity (dynamic simulations for amount of CO2 injected of 27 kt only); the project is not intended as demo/industrial but uses same aquifer as the Polish demo project, and is about 50 km from the likely demo site
POTENTIAL R&D CONSORTIUM	By now a drilling company and two research partners (PGI-NRI & AGH-UST) intend to carry out the project; CO2 processing industry - Messer & Linde have been expected to provide CO2
CLOSE EMMISSION SOURCES	Three big power & CHP plants (Konin, Pątnów, Adamów) within 50 km radius - owned by one of potential funding partners - results would be used by them, many smaller heating plants; Bełchatów plant is about 120 km away
PROJECT BUDGET	19 M€ - the scope approved in the research injection permit granted by Ministry of Environment
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	Within the demo project only (except from research on capture technologies in laboratory scale) - no direct connection
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	Possible - local communities of the area in question are interested in the use of low enthalpy geothermal
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	Konin power plant is building a biomass fired boiler
POTENTIAL COMBINATION WITH CO2 USES	Not yet, but possible
STATE SUPPORT	The Deputy Minister of Environment who pushed forward the project has been replaced - the new one has other priorities; the local authority sold a piece of land for PGI where the injection site is planned
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	The area has a long history of salt mining and further - lignite mining (Konin, Pątnów and Adamów plants) but the idea of pilot injection has been presented to the local authorities only (not to a wider sample of residents)
COMMENTS	The problem is an unclear stand of the central government to CCS as a whole

LUSITANIA	
COUNTRY	Portugal
TYPE OF STORAGE	Saline aquifer
LOCATION (ON/OFF)	Onshore
DEPTH TO TOP OF STORAGE FM	>1600m
STORAGE FORMATION LITHOLOGY	Sandstone
SEALING FORMATION LITHOLOGY	Sequence of evaporites (salt and gypsum layers) marls and clays, more than 1000 m thick.
STORAGE REQUIREMENT (PILOT)	8 - 10 kt/year
ESTIMATED STORAGE CAPACITY	90 – 180 Mt, screening formulae. It can be upgraded to demonstration scale site
POTENTIAL R&D CONSORTIUM	University of Évora, National Laboratory of Energy and Geology (LNEG)
CLOSE EMMISSION SOURCES	Pego coal power plant, Maceira/Liz and Cibra/Patais cement plants, totalling 5.14 MT CO_2/year on average from 2005/2009
PROJECT BUDGET	4-5 M€ implementation costs
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	Not planned
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	Not planned
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	Not planned
POTENTIAL COMBINATION WITH CO2 USES	Not planned
STATE SUPPORT	National authorities support the project, but funding only in-kind.
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	
COMMENTS	

TURCENI	
COUNTRY	Romania
TYPE OF STORAGE	CGS+EOR
LOCATION (ON/OFF)	Onshore, north of Craiova, Bradesti
DEPTH TO TOP OF STORAGE FM	2200 m
STORAGE FORMATION LITHOLOGY	Triasic sansdstones
SEALING FORMATION LITHOLOGY	shales
STORAGE REQUIREMENT (PILOT)	100 kt
ESTIMATED STORAGE CAPACITY	17.5 Mt
POTENTIAL R&D CONSORTIUM	GeoEcoMar, Romgaz, OMV Petrom, ISPE, EC Turceni
CLOSE EMMISSION SOURCES	EC Turceni
PROJECT BUDGET	20-40 Mil Euros
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	Yes
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	No
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	No
POTENTIAL COMBINATION WITH CO2 USES	CO_2 can be use for oil industry
STATE SUPPORT	Yes, National and local administration support the project, funding is under discussion
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	Jobs
COMMENTS	

ROVINARI	
COUNTRY	Romania
TYPE OF STORAGE	Saline aquifer
LOCATION (ON/OFF)	Onshore, south of Rovinari, near Matasari
DEPTH TO TOP OF STORAGE FM	1400 m
STORAGE FORMATION LITHOLOGY	Sarmatian sands, sandstones interlayering with silts and shales
SEALING FORMATION LITHOLOGY	Shales
STORAGE REQUIREMENT (PILOT)	100 kt
ESTIMATED STORAGE CAPACITY	50 Mt
POTENTIAL R&D CONSORTIUM	GeoEcoMar, Romgaz, ISPE, Rompetrol, EC Rovinari
CLOSE EMMISSION SOURCES	EC Rovinari
PROJECT BUDGET	20-40 Mil Euros
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	Yes
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	No
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	No
POTENTIAL COMBINATION WITH CO2 USES	CO_2 can be used for oil industry
STATE SUPPORT	Yes, National and local administration support the project, funding is under discussion
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	Jobs
COMMENTS	

CRAIOVA	
COUNTRY	Romania
TYPE OF STORAGE	Depleted hydrocarbon field
LOCATION (ON/OFF)	Onshore, near Craiova, Samnic-Ghercesti field
DEPTH TO TOP OF STORAGE FM	1500 m
STORAGE FORMATION LITHOLOGY	Middle Jurasic limy sandstones, siliceous sandstones, limestones, dolomites, marls, shales and siderites
SEALING FORMATION LITHOLOGY	Shales
STORAGE REQUIREMENT (PILOT)	1000 kt
ESTIMATED STORAGE CAPACITY	10 Mt
POTENTIAL R&D CONSORTIUM	GeoEcoMar, Romgaz, OMV Petrom, ISPE, EC Craiova
CLOSE EMMISSION SOURCES	EC Craiova
PROJECT BUDGET	20-40 Mil Euros
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	Yes
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	No
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	No
POTENTIAL COMBINATION WITH CO2 USES	CO_2 can be used for oil industry
STATE SUPPORT	Yes, National and local administration support the project, funding is under discussion
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	Jobs
COMMENTS	

GALATI	
COUNTRY	Romania
TYPE OF STORAGE	Depleted hydrocarbon field
LOCATION (ON/OFF)	Onshore, 60 km from Galati, Ghergheasa
DEPTH TO TOP OF STORAGE FM	2000 m
STORAGE FORMATION LITHOLOGY	Pontian formation ,fine-grained marly sands, generally unconsolidated with marly intercalations
SEALING FORMATION LITHOLOGY	marls
STORAGE REQUIREMENT (PILOT)	100 kt
ESTIMATED STORAGE CAPACITY	50 Mt
POTENTIAL R&D CONSORTIUM	GeoEcoMar, Romgaz, ISPE, Arcelor Mittal Steel Galati
CLOSE EMMISSION SOURCES	Arcelor Mittal Steel Galati
PROJECT BUDGET	20-40 Mil Euros
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	Yes
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	No
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	No
POTENTIAL COMBINATION WITH CO2 USES	CO_2 can be used for oil industry
STATE SUPPORT	Yes, National and local administration support the project, funding is under discussion
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	Jobs
COMMENTS	

NAME OF SITE: LÁB	
COUNTRY	Slovakia - Vienna basin
TYPE OF STORAGE	Depleted oil/gas field. Water drive regime with connection to aquifer.
LOCATION (ON/OFF)	Onshore
DEPTH	1350 – 1450m
STORAGE FORMATION LITHOLOGY	Limestone sandstone
SEALING FORMATION LITHOLOGY	Clay – proven storage integrity for geological timescales
STORAGE CAPACITY	~ 2,5 Mt (initially intention is to store 100 kt)
POTENTIAL R&D CONSORTIUM	State Geological Institute Dionýz Štúr (SGUDS) – is scientific and research institute of the Ministry of Environment and is responsible for providing geological research and exploration of Slovak Republic area. NAFTA, a.s. – company with long term experience in: - Underground gas storage - Exploration and production of hydrocarbons
CLOSE EMMISSION SOURCES	The emission sources (local industrial areas) are located within distance of 40 km from site - refinery Slovnaft ~ 1,5 Mt/yr. and several other industrial sources in distance from 2 km up to 25 km (cement production, automotive etc.) with combined emissions of ~ 1Mt/yr.
PROJECT BUDGET	~ 8,0 M € (only for storage site – construct (re-use) treatment station,

	reconstruct well connections, re-used wells workovers and completion missing geologic data). Note: Existing wells and partly gas production infrastructure is available for further use by a pilot project.
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	-
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	In this location 4 exploration licenses for geothermal energy are awarded. The project may seek further cooperation with geothermal projects.
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	A biogas station is located within a distance of 50 km from the site. There is an intention to construct more Biogas stations in the coming years.
POTENTIAL COMBINATION WITH CO2 USES	Area is used for agriculture prosperity (there is potential for the seasonal use of CO_2 for greenhouses).
STATE SUPPORT	The EU CCS Directive is fully implemented into national law and CO_2 storage is legally possible. No national funding scheme is existing and no international funding has been requested until now.
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	Potential conservation of existing employment. The area is highly industrialised with a lot of emissions. The industrial areas are located within a distance from 2 km from site. Safety: Verified geological structures - long experience in hydrocarbons production in object area, available

	comprehensive geological and reservoir engineering data.
COMMENTS	Within years 2008 and 2009 a state project defining appropriate locations for CO_2 sequestration was performed. The aim was to map, categorize, rank and screen the feasible CO_2 sequestration sites. The above proposed site was selected based on the results of this project.

NAME OF SITE: PTRUKŠA	
COUNTRY	Slovakia - Trans Carpathian basin
TYPE OF STORAGE	Depleted gas field, gas drive regime
LOCATION (ON/OFF)	Onshore
DEPTH	1450 – 1550m, 1800 - 1850m
STORAGE FORMATION LITHOLOGY	Sandstone
SEALING FORMATION LITHOLOGY	Limestone, mice clay - proven storage integrity for geological timescales
STORAGE CAPACITY	~ 2,9 Mt (initially intention is to store 100 kt)
POTENTIAL R&D CONSORTIUM	State Geological Institute Dionýz Štúr (SGUDS) – is scientific and research institute in the Ministry of Environment and is responsible for providing geological research and exploration of Slovak Republic area. NAFTA, a.s. – company with long term experience in: - Underground gas storage - Exploration and production of hydrocarbons
CLOSE EMMISSION SOURCES	The emission sources) are located within distance of 50 km from site – U.S. steel ~ 7,0 Mt/yr. and several other industrial sources in distance up to 25 km (Power Plant ~ 0,7 Mt/yr., chemistry, wood products industry etc.).
PROJECT BUDGET	~ 9,0 M € (only for storage site – construct (re-use) treatment station, reconstruct well connections, re-used wells workovers and completion missing geologic data).

	Note: Existing wells and partly gas production infrastructure is available for further use by a pilot project.
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	-
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	Area has high geothermal potential (high geothermal gradient). In this location 29 exploration licenses for geothermal energy are awarded. The project may seek further cooperation with geothermal projects.
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	The 6 Biogas stations are located within a distance from 20 up to 100 km from the site.
POTENTIAL COMBINATION WITH CO2 USES	Area is used for agriculture prosperity (there is potential for the seasonal use of CO_2 for greenhouses).
STATE SUPPORT	The EU CCS Directive is fully implemented into national law and CO_2 storage is legally possible. No national funding scheme is existing and no international funding has been requested until now.
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	Keeping employment after stop of hydrocarbon production (High unemployment rate in Košice district in 2011 was 19,6%, in Prešov district in 2011 was 17,8%). Safety: Verified geological structures - long experience in hydrocarbons production in object area, available comprehensive geological and reservoir engineering data.

COMMENTS	Within years 2008 and 2009 a state project defining appropriate locations for CO_2 sequestration was performed. The aim was to map, categorize, rank and screen the feasible CO_2 sequestration sites. The above proposed site was selected based on the results of this project.

NAME OF SITE: STRETAVA	
COUNTRY	Slovakia – Trans Carpathian Basin
TYPE OF STORAGE	Depleted gas field, gas drive regime
LOCATION (ON/OFF)	Onshore
DEPTH	1100 – 1200m, 1700 – 1750m
STORAGE FORMATION LITHOLOGY	Sandstone
SEALING FORMATION LITHOLOGY	Clay, tuffs - proven storage integrity for geological timescales
STORAGE CAPACITY	~ 1,6 Mt (initially intention is to store 100 kt)
POTENTIAL R&D CONSORTIUM	State Geological Institute Dionýz Štúr (SGUDS) – is scientific and research institute in the Ministry of Environment and is responsible for providing geological research and exploration of Slovak Republic area. NAFTA, a.s. – company with long term experience in: - Underground gas storage - Exploration and production of hydrocarbons
CLOSE EMMISSION SOURCES	The emission sources) are located within distance of 50 km from site – U.S. steel ~ 7,0 Mt/yr. and several other industrial sources in distance up to 25 km (Power Plant ~ 0,7 Mt/yr., chemistry, wood products industry etc.).
PROJECT BUDGET	~ 8,0 M € (only for storage site – construct (re-use) treatment station, reconstruct well connections, re-used wells workovers and completion missing geologic data).

	Note: Existing wells and partly gas production infrastructure is available for further use by a pilot project.
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	-
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	Area has high geothermal potential (high geothermal gradient). In this location 29 exploration licenses for geothermal energy are awarded. The project may seek further cooperation with geothermal projects.
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	The 6 Biogas stations are located within a distance from 20 up to 100 km from the site.
POTENTIAL COMBINATION WITH CO2 USES	Area is used for agriculture prosperity (there is potential for the seasonal use of CO_2 for greenhouses).
STATE SUPPORT	The EU CCS Directive is fully implemented into national law and CO_2 storage is legally possible. No national funding scheme is existing and no international funding has been requested until now.
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	Keeping employment after stop of hydrocarbon production (High unemployment rate in Košice district in 2011 was 19,6%, in Prešov district in 2011 was 17,8%). Safety: Verified geological structures - long experience in hydrocarbons production in object area, available comprehensive geological and reservoir engineering data.

COMMENTS	Within years 2008 and 2009 a state project defining appropriate locations for CO_2 sequestration was performed. The aim was to map, categorize, rank and screen the feasible CO_2 sequestration sites. The above proposed site was selected based on the results of this project.

NAME OF SITE: MARCELOVÁ	
COUNTRY	Slovakia, Danube basin
TYPE OF STORAGE	Local aquifer, mineralization 90g/l
LOCATION (ON/OFF)	Onshore
DEPTH	1037,5 – 1045,5m, 1739,5 – 1761m
STORAGE FORMATION LITHOLOGY	Sandstones, limestones, dolomites, shales
SEALING FORMATION LITHOLOGY	Carbonates, clays. According to hydrogeochemical characteristic the structure is closed.
STORAGE CAPACITY	70 Mt – potential to continue from the pilot stage to the industrial stage.
POTENTIAL R&D CONSORTIUM	State Geological Institute of Dionýz Štúr (SGUDS) – is scientific and research institute in the Ministry of Environment and is responsible for providing geological research and exploration of Slovak Republic area, creation of a geological information system; collection, recording and distribution the results of geological works carried out in Slovakia. SGUDS has solved governmental mission regarding possibilities for CO2 storage in the Slovakian territory. NAFTA, a.s. – company with long experience in production of hydrocarbons. Core activities: - Mineral exploitation and activities performed using mining methods - Prospecting for and exploration of fields of listed minerals - Development of hydrocarbon fields, - and hydrocarbon lifting, treatment and refining - cooperation with SGUDS DUSLO a.s. – chemical factory producing fertilizers and 500 000 t of CO2 annualy with purity above 99%
CLOSE EMMISSION SOURCES	DUSLO a.s. Šaľa, member of group AGROFERT- ca 50 km
PROJECT BUDGET	25 mil. EUR - estimation
POTENTIAL COMBINATION WITH	Capture from the DUSLO Šaľa according to pre-feasibility study due to high purity of CO2

CAPTURE PROJECTS	is reduced only at the pressuring of CO_2
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	Probability is very high, the temperature in the reservoir is 63 – 65,5^0 C
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	This issue is pretty actual within this region
POTENTIAL COMBINATION WITH CO2 USES	The area belongs to the most developed from the agriculture point of view in the Slovakia. Utilisation for horticulture purposes is high probable
STATE SUPPORT	Perhaps without support
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	Support for decreasing of unemployment level, creation of new working places
COMMENTS	The added value are calculated reserved of Iodium and Bromium (84,14t + 724,32 t). The waters with content of these elements are shortage at the market (balneology). The expected exploitation time for aquifer is 20 years what responds to life time of average storage site of CO_2. In the other words – exploitation of aquifer may release a space for CO_2.

HONTOMÍN	
COUNTRY	SPAIN
TYPE OF STORAGE	Saline aquifer
LOCATION (ON/OFF)	Onshore
DEPTH	1600 m
STORAGE FORMATION LITHOLOGY	Limestones (partially dolomitized and fractured)
SEALING FORMATION LITHOLOGY	Marls and silts
STORAGE CAPACITY	Small but not calculated
POTENTIAL R&D CONSORTIUM	A big consortium of research institutions, Universities, and industry, work already in Hontomin.
CLOSE EMMISSION SOURCES	The closed emission source is located at 150 km. There are some potential users of the data (ENDESA, CEPSA, U. Fenosa, etc.)
PROJECT BUDGET	Total cost of Hontomin infrastructure plus research related is of around 30 M€.
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	Hontomin plant is integrated with the oxycombustion Compostilla experimental capture plant. Moreover, the postcombustion experimental plant of Asturias (La Pereda) could be easily connected.
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	Although there is some manifested interest in geothermal energy in the region, there are not real plans in the near future.
POTENTIAL COMBINATION WITH	Compostilla experimental plant of capture also works with biomass.

BIOMASS CO2 CAPTURE	
POTENTIAL COMBINATION WITH CO2 USES	MATGAS, institution specialized in CO2 uses, form part of CIUDEN consortium.
STATE SUPPORT	CIUDEN is a public foundation supported mainly by national funds. Hontomin has a strong national support
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	Hontomin has a very good relationship with local and regional institutions and communities.
COMMENTS	

NAME OF SITE: UK onshore	
COUNTRY	UK
TYPE OF STORAGE	Saline aquifer
LOCATION (ON/OFF)	Onshore
DEPTH	800 – 1200 m
STORAGE FORMATION LITHOLOGY	Sandstone (Sherwood Sandstone Group. Offshore these formations mostly fall within the Bunter Sandstone Group and basal Permian Sands). A suitable closure has not been identified but there are a few small oil fields in this region indicating that buoyant fluids can be trapped for geological timescales.
SEALING FORMATION LITHOLOGY	Mudstone (Mercia Mudstone Formation) - proven storage integrity for geological timescales for buoyant fluids as this forms a seal in the North Sea
STORAGE CAPACITY	Relatively small, on the tens of kt scale as closures are likely to have small capacity
POTENTIAL R&D CONSORTIUM	An initial study of this area was conducted by a private – public partnership for the CASSEM project (Amec plc, British Geological Survey, University of Edinburgh, Heriot Watt University, Marathon, Schlumberger, Scottish Power, Scottish and Southern Electric, Tyndall Centre). A similar public-private consortium would need to be identified for a pilot to take place.
CLOSE EMISSION SOURCES	There is a cluster of sources around this region including the Drax (4000 MW) and Ferrybridge (1960 MW) power stations in North Yorkshire are near the region which was studied for storage. A few industrial plants (iron & steel, refineries,

	chemical, cement) are also located in this region.
PROJECT BUDGET	Unknown, likely to cost > 1 M Euros
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	The site lies near the Ferrybridge power station where, in 2011, a demonstration capture plant was opened which captures 100 tonnes of CO_2 per day.
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	The east coast of Yorkshire and Lincolnshire has been identified as having some potential for geothermal exploitation. On the east coast, boreholes penetrating the Permo-Triassic Sherwood Sandstone Formation have identified aquifers with temperatures greater than 40 – 60 °C. The Cleethorpes borehole in north Lincolnshire has recorded aquifer temperatures of 44 – 55°C in the Sherwood Sandstone Formation and 64 °C in the basal Permian sands.
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	There are a few small biomass power plants planned but these are not particularly close to the storage area studied. Biomass is utilised at the nearby Drax power station.
POTENTIAL COMBINATION WITH CO2 USES	If CO_2-EOR were to happen in the North Sea, this could offer the option to utilise the CO_2. The Don Valley project proposes to use CO_2 from a new IGCC power-station for EOR in the Central North Sea.
STATE SUPPORT	The EU CCS Directive is fully implemented into national law and CO_2 storage is legally possible. Nation funding is focussed on the UK demonstration competition and the UK CCS research centre. Some co-funding may be possible through the UKCCSR, but industrial

	sponsorship would be needed to fill the funding gap.
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	Job creation during construction would be welcome in this industrial region.
COMMENTS	As the Sherwood Sandstone Group onshore is a major aquifer highly detailed characterisation of the pilot site and MMV would be required to avoid contamination this valuable resource. Two of the units at Ferrybridge will close by 2015 at the latest as they have opted out of the Large combustion plant directive and by then are expected to have used up their allocated operating hours. A 68 MW multifuel generation plant it currently being constructed at the Ferrybridge site. Drax power station is part of the UK competition for a demonstration project as part of the White Rose project. An offshore storage pilot for the UK would not be feasible as costs would be too high to justify a small-scale injection.

NAME OF SITE: UK onshore	
COUNTRY	UK
TYPE OF STORAGE	Migration, leakage, monitoring and impacts controlled release in Scottish sea loch (Ardmucknish Bay).
LOCATION (ON/OFF)	offshore
DEPTH	Water depth of 12 m and release point 12 m below sea bed
STORAGE FORMATION LITHOLOGY	Migration of CO_2 through unconsolidated recent sediment has been studied (2010 – present)
SEALING FORMATION LITHOLOGY	No seal
STORAGE CAPACITY	None
POTENTIAL R&D CONSORTIUM	Plymouth Marine Laboratory, British Geological Survey, National Oceanography Centre, University of Edinburgh (with University of Bristol and Durham University), Heriot-Watt University, University of Southampton, DNV, and Scottish Association for Marine Science. Japanese research consortium: National Institute of Advanced Industrial Science and Technology (AIST); CREIPI; JANUS; International Institute for carbon-neutral energy research Kyushu University; Research Institute of Innovative Technology for the Earth; University of Tokyo (Todai)
CLOSE EMISSION SOURCES	CO_2 purchased from an industrial supplier was released over a period of 36 days in May 2012, followed by 90 days of monitoring and impacts sampling.
PROJECT BUDGET	Around £1.5 million

POTENTIAL COMBINATION WITH CAPTURE PROJECTS	None.
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	None
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	None
POTENTIAL COMBINATION WITH CO2 USES	None
STATE SUPPORT	No
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	Controlled release and monitoring led by local marine research institute employer. Local suppliers of food and accommodation, some local civil engineering. Temporary visitor attraction
COMMENTS	Local public engagement activities have been undertaken in conjunction with existing public interaction by the marine institute. Response has been predominantly supportive with positive results.

ANNEX II

FULL ARTICLE PRESENTED TO GHGT-11 CONGRESS (WILL BE PUBLISHED BY ENERGY PROCEDIA)

GHGT-11

CCS Directive transposition into national laws in Europe: progress and problems by the end of 2011

1Alla Shogenova[a], Kris Piessens[b], Jüri Ivask[a], Kazbulat Shogenov[a], Roberto Martínez[c], Kristin M. Flornes[d], Niels E. Poulsen[e], Adam Wójcicki[f], Saulius Sliaupa[g], Ludovít Kucharič[h], Alexandra Dudu[i], Sergio Persoglia[j], Sam Holloway[k] and Bruno Saftic[l]

[a]Institute of Geology, Tallinn University of Technology, Ehitajate tee 5, Tallinn 19086, Estonia
[b]Geological Survey of Belgium, Royal Belgian Institute of Natural Sciences, Jennerstreet 13, 1000 Brussels, Belgium
[c]Instituto Geológico y Minero de España (IGME), Ríos Rosas 23, 28003 Madrid, Spain
[d]International Research Institute of Stavanger (IRIS), Prof. Olav Hanssensvei 15, N-4068 Stavanger, Norway
[e]Geological Survey of Denmark and Greenland (GEUS), Ø. Voldgade 10, DK-1350 Cph. K, Denmark
[f]Polish Geological Institute - National Research Institute, 4th Rakowiecka Str., 00-975 Warsaw, Poland
[g]Nature Research Centre, Akademijos 2, LT–08412 Vilnius, Lithuania
[h]State Geological Institute of Dionýz Štúr (ŠGÚDŠ), Mlynská dolina 1, 817 04 Bratislava, Slovakia
[i]National Institute of Marine Geology and Geoecology Str. Dimitrie Onciul, Nr. 23-25, RO-024053, Bucharest, Romania
[j]Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS), Borgo Grotta Gigante 42/C, 34010 Sgonico , Italy
[k]BGS, Keyworth, Nottingham, NG12 5GG, United Kingdom
[l]University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, Croatia

Abstract

The EU CCS Directive transposition process and related issues in 26 European countries, comprising 24 EU member states, Norway and Croatia were studied in the EU FP7 project: "CGS Europe" in 2011-2012. By the end of 2011 the transposition of the Directive into national law had been approved by the European Commission (EC) in Spain only, but had been approved at national/jurisdictional level in 12 other countries (Austria, Denmark, Estonia, France, Greece, Ireland, Italy, Latvia, Lithuania, the Netherlands, Slovakia and Sweden) and two regions of Belgium. By January 2012, the European Commission had assessed and approved national submissions of CCS legal acts transposing the Directive in Denmark, France, Italy, Lithuania, Malta, the Netherlands and Slovenia. Implementation in the UK was completed in February 2012 and by end March 2012, implementation at national level was also complete in Bulgaria, Czech Republic, Portugal and Romania.

Belgium, Croatia, Finland, Germany, Hungary, Norway and Poland had not finished the transposition of the CCS Directive by end March 2012. The process had been complicated by ongoing political debates in Norway, public opposition in Germany and ministerial elections in Poland. More than 20 operating, developing and planned CCS pilot and demonstration projects have been identified in nine European countries. Storage capacity was estimated by CGS Europe project partners as "sufficient at national level" in 17 countries.

Selection and/or peer-review under responsibility of GHGT

Keywords: Carbon dioxide; CCS Directive; European country; CO_2 storage capacity; Climate/energy policy; Public acceptance; Onshore and offshore storage

1. Introduction

Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide was published on 5 June 2009, and entered into force on 25 June 2009. This directive established a legal framework for the environmentally safe geological storage of carbon dioxide (CO_2) to contribute to the fight against climate change. In article 39: "Transposition and transitional measures", it is stated that "Member States shall

* Corresponding author. Tel.: +372-566-44-668; fax: +372-620-3011
E-mail address: alla@gi.ee

bring into force the laws, regulations and administrative provisions necessary to comply with this Directive by 25 June 2011", that they "shall communicate to the Commission the text of the main provisions of national law which they adopt in the field covered by this Directive" and they "shall ensure" that storage sites "are operated in accordance with the requirements of this Directive by 25 June 2012" [1].

The aims of this article are to:

- Give an overview of the progress towards, and results of, the transposition of the CCS Directive into national laws up to spring 2012.
- Describe issues that emerged during the transposition process in 26 European countries.
- Compare the situation after the deadline for transposition (25 June 2011) in different EU member states, to reveal country-specific and generic issues.
- Make a comparative analysis of the transposition process in Europe taking into account different geological, political and financial situations, various levels of research and technological development, and differences in public awareness and acceptance of CCS technology.

The study was undertaken because it was felt that comparison of the problems and progress in the CCS regulatory process in different countries would aid understanding of driving forces, barriers and prospects for implementation and regulation of CCS technology at both the national and international levels.

2. Data and methods

Status, progress and problems in the CCS Directive transposition process were monitored in all countries participating in the EU FP7 "CGS Europe" project at the end of January, end of April, and September-December 2011 and were updated in spring 2012. In most cases, data were collected by the participants in cooperation or consultation with the national legal authorities responsible for the Directive transposition.

The question of whether sufficient storage capacity was likely to be present in participants' countries was also examined. Estimation of storage capacity as sufficient, insufficient or absent is based on the results obtained, or approach used, in the FP6 "EU Geocapacity" project. In this project, CO_2 storage capacity was estimated using common principles and formulae, and calculated capacity was compared with national large industrial point source annual emissions (from point sources emitting >100 000 tonnes CO_2 per year) [2]. In the present study CO_2 storage capacity is described as sufficient if reported conservative estimates of storage capacity are large enough for storage of national emissions from large industrial point sources for 25 years or more.

3. Results

3.1. Progress in CCS directive transposition up to spring 2012

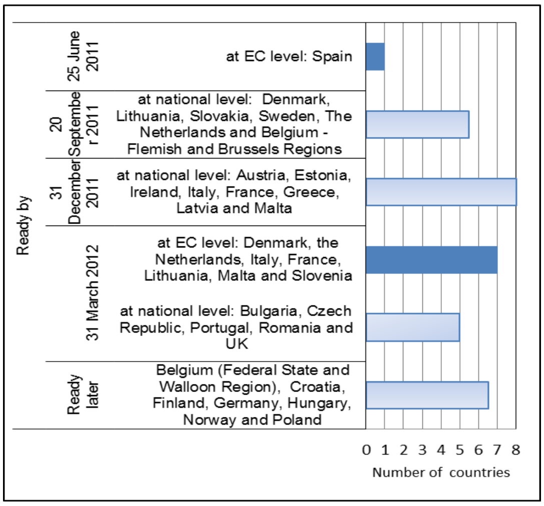

Fig. 1. Readiness of CCS Directive transposition at national and European Commission levels in 27 countries (the transposition for Malta is shown, but this country was not covered in the CGS Europe survey)

January 2011: The pioneering work in CCS legislation in the EU was undertaken by the UK, which started the process in 2008 by implementation of the UK Energy Act shortly before the CCS Directive was issued. The UK Energy Act established a regulatory framework for offshore CO_2 storage, but also provided sufficient flexibility to transpose the CCS Directive [3].

A further 15 EU countries and Norway started work on transposition of the CCS Directive in 2009-2010. The Directive is typically transposed through new laws and/or amendments of existing regulations. Among the 26 countries, only Spain reported their readiness for the full transposition of the CCS Directive at the beginning of 2011 (the relevant law was published by the Official State Bulletin on December 29th 2010) and transposition in Spain was acknowledged by the EC before their deadline for transposition, 25th June 2011 (Fig. 1).

June 2011: Denmark (24/05/2011) and Sweden (22/06/2011) reported their readiness at national level before the deadline (25th June 2011). Denmark and Sweden decided to temporarily ban CO_2 storage, Denmark banned onshore storage until 2020 to gain more experience from on-going projects and Sweden did so in order to meet the deadline and to have enough time for preparation of regulations permitting offshore storage. Nine of the Member States studied (Austria, Belgium, Denmark, Finland, France, Ireland, Latvia, Lithuania, and the UK) had communicated partial transposition measures to the EC and 13 countries (Bulgaria, Czech Republic, Estonia, Germany, Greece, Italy, Hungary, The Netherlands, Poland, Portugal, Slovakia, Slovenia and Sweden) had not communicated any progress towards transposition before the deadline. The governments of Romania (29/06/2011) and Lithuania (28/06/2011) completed the transposition of the CCS Directive at national level in June 2011, very shortly after the deadline.

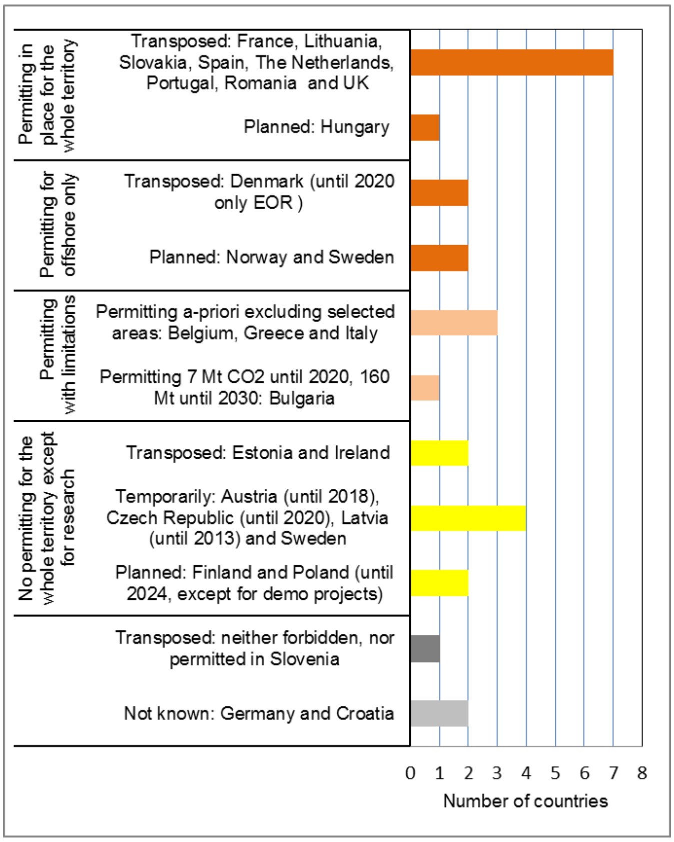

Fig. 2. Permitting/no permitting of CO_2 storage in national laws published and submitted to EC (transposed) and in draft legislations (planned) in the studied countries

July-December 2011: Early in this period, Romania informed the EC about transposition of the CCS Directive, while all other 25 EU member states including Lithuania received letters from the EC in July 2011 with formal notice about non-communication infringement procedures.

During this period Slovakia (12/07/2011), Italy (01/08/2011) and The Netherlands (10/09/2011) completed the CCS Directive transposition at the national level.

After consideration of the relevant published Romanian law, the EC found it incomplete and Romania received formal notice of non-communication infringement procedures in November 2011.

By the end of 2011 the transposition of the Directive into national law was approved by the European Commission (EC) in Spain only, although it was indicated to be ready at national/ jurisdictional level in 13 countries (Austria, Denmark, Estonia, France, Greece, Ireland, Italy, Latvia, Lithuania, Malta, Slovakia, Sweden and The Netherlands) and two regions of Belgium (Fig. 1).

Spring 2012: Early in 2012 Romania published additional laws (according to EC requirements). Bulgaria, Portugal, Slovenia and Czech Republic transposed the CCS Directive at the national level and the UK finalised their national transposition process (Fig. 1).

In January 2012 the European Commission had assessed further transpositions of CCS Directive, and seven more countries (Denmark, the Netherlands, Italy, France, Lithuania, Malta and Slovenia) were accepted to have fully communicated their transposition mechanisms to the Commission.

The remaining investigated countries (Belgium: Federal State and Walloon Region, Croatia, Finland, Germany, Hungary, Norway and Poland) had not finished national transposition of the Directive by spring 2012 (CCS laws had not been published at the time of submission of this publication). Consequently, the process of transposing the CCS Directive into national law and the assessment by the EC of whether the relevant national laws properly transpose the Directive is still on-going in 2012 (Fig. 1).

3.2. Permitting or prohibiting CO_2 storage

As a result of the on-going transposition process, CO_2 storage is now permitted in eight of the studied countries (France, Lithuania, Portugal, Romania, Slovakia, Spain and the Netherlands) and is planned to be permitted in Hungary (Fig. 2). Only offshore storage is likely to be permitted in the near future in the UK. Offshore storage mainly for EOR, is permitted in Denmark before 2020; onshore storage in Denmark is banned until 2020. CO_2 storage is permitted excluding seismic areas in Italy, permitted except in selected areas (without storage capacity) in Belgium, and excluding areas where the storage complex extends beyond Hellenic territory in Greece. CO_2 storage is permitted with limitations in Bulgaria (storage of up to 7 Mt CO_2 until 2020 and 160 Mt CO_2 until 2030). CO_2 storage is temporarily forbidden in Austria (until 2018), Latvia (until 2013), Sweden, and the Czech Republic (until 2020). CO_2 storage is forbidden except for research and development in Estonia and Ireland. CO_2 storage is planned to be forbidden in Finland, and in Poland, except for demonstration projects (until 2024). The situation was still unclear in Germany, as two versions of the Climate Bill have been rejected to date and its new edition is still under discussion in the German Government. CO_2 storage is neither forbidden nor permitted in Slovenia. In all the countries where CO_2 storage is forbidden, or planned to be forbidden, the exception from Article 2 of the Directive is usually included for activities “with a total intended storage below 100 kilotonnes, undertaken for research, development or testing of new products or processes”, and requirements to newly constructed power stations to be “capture ready” with planned transportation and storage site (which in these cases will have to be transboundary).

4. Issues around transposition of the Directive

4.1. Storage capacity and conflicts of interest

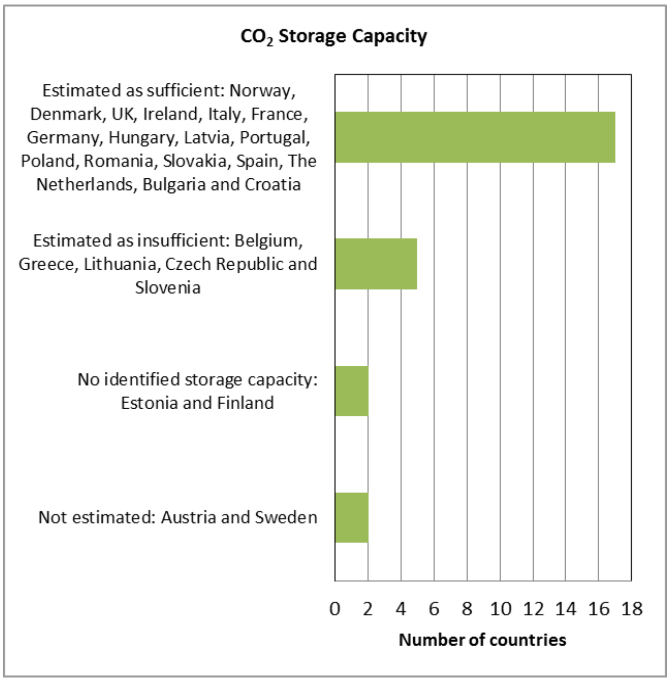

Fig. 3. Sufficiency estimation of CO_2 storage capacity in the studied countries

Estimates of CO_2 storage capacity were undertaken in the studied countries in the EU FP5 GESTCO project, EU FP6 Geocapacity project and also in independent national projects in some countries [1, 4-6]. The EU Geocapacity project estimated European storage capacity to be conservatively 127 Gt CO_2, comprising 97 Gt in saline formations, 20 Gt in hydrocarbon fields and 1 Gt in coal seams [2]. Storage capacity was estimated by the CGS Europe project partners as “sufficient at national level” in 17 countries (Fig. 3). The Norwegian partners in this project consider that Norway could potentially offer capacity to other countries for cross-border storage [7]. Storage capacity was estimated as “insufficient” in five countries, as “not identified” in Estonia and Finland and “not yet estimated” in Sweden and Austria.

The CCS Directive includes the right

of Member States not to allow any storage, or to give priority to any other use of the underground [1]. After transposition of the Directive into national laws, CO_2 storage capacity has been variably considered as a geological resource which either has equal priority for exploitation relative to other resources (as in Spain and France), or has lower priority for exploitation (Poland, Slovakia, Portugal).

The CCS Directive states that Member States should ensure that no conflicting uses are permitted on the storage site during the period of validity of the exploration and storage permits [1]. Many countries reported that they have, or could have, conflict of interests between CCS and other legitimate activities. The most commonly cited conflicts of interests reported are with hydrocarbon exploration and production, drinking water, natural gas storage and geothermal resources.

The CCS regulations in most countries do not usually allow overlap between existing hydrocarbon production licences and CCS licences although there are exceptions (e.g. Spain, Lithuania). However, if a hydrocarbon field is in a state of depletion, many countries allow CO_2 storage combined with CO_2 injection as an enhanced hydrocarbon recovery technique. The production of other mineral resources could result in conflict of interests with CCS if within a comparable depth range, or deeper than the CO_2 storage complex. Shallow use of the subsurface is not necessarily an obstacle to CO_2 storage and vice versa. Geothermal applications present a possible conflict of use of saline aquifers; this is particularly the case for onshore aquifers at present, but could also apply to offshore aquifers in the future. However, interactions with geothermal projects are not necessarily negative. A number of studies have been published worldwide proposing the combined use of geothermal exploitation and CGS in the same place [8].

4.2. National Policy in CCS and financial matters

In 2011 CCS was included in national energy/climate strategy/policy of nine of the studied countries (Fig. 4), while Poland and Spain reported that their policy in CCS would be only to allow planned demonstration projects. There was no reported strong CCS policy in the climate and energy strategic plans of the other countries studied.

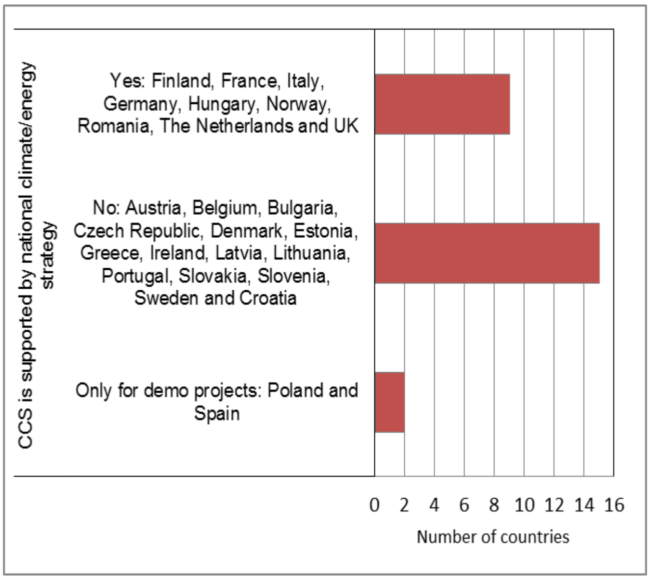

Fig. 4. Availability of CCS in national energy and climate strategy in the studied countries

The United Kingdom has one of the most proactive CCS policies in Europe, indeed in the world. Political support for CCS began in 2002 in the Energy Review. At present there is shared political agreement on CCS deployment in the UK with government commitment to fund four demonstration projects. Consequently on 03 April 2012, UK Energy and Climate Change Secretary Edward Davey launched a new CCS Commercialisation Programme, including GBP 1 billion of capital funding to support commercial-scale CCS with a view to enabling commercial deployment 'in the 2020s'.

In Germany, in 2010, CCS technology was included in the German Federal Government's Energy Strategy which included ambitious reduction targets for greenhouse gas emissions for the period 2020-2050. Two demonstration CCS projects were to be built by 2020 and further export of CCS technology to developing countries, as well as application of CCS in the steel and cement industry sectors were mentioned in the German strategic plans. However, implementation of the CCS Directive in Germany ran into difficulties. Two versions of CCS Bill have already been rejected by Parliament several times since 2009. One of the reasons for this is the opposition of the Green Party in Germany, which have a much stronger position in Germany than in the UK [9].

Italy, France and The Netherlands provide examples of countries that have CCS plans in their energy and climate policies and which finished national transposition in 2011. Their transpositions were accepted by the EC in January 2012. Slovakia and Lithuania, both countries without strong CCS objectives, published CCS laws in their countries in August and September 2011 respectively, and Lithuanian CCS regulations were accepted by the EC in January 2012.

Financial problems related to the possible implementation of CCS technology were reported by 8 countries (Denmark, Estonia, Greece, Hungary, Italy, Latvia, Poland and Slovakia). On the other hand, government financial and/or political support and industrial support for CCS demonstration projects are presently available in France, Germany, Italy, the Netherlands, United Kingdom, Norway, Romania, Poland and Spain. By the end of 2011 several pilot- or demonstration-scale CO_2 capture plants were operating and a number of full chain CCS demonstration projects were planned in Europe. Six of these projects were selected in 2009 by the European Energy Programme for Recovery (EEPR) for European co-funding. 13 projects from seven countries (including 4 projects supported by EEPR) were submitted in 2011 for NER 300 funding. Only 11 of 13 projects submitted took part in the competition, because one of the seven submitted by the UK (Longannet) is no longer supported by the UK government, and Jänschwalde project was withdrawn by Vattenfall because of the problems with the Directive transposition in Germany. In July 2012 the European Commission selected 8 CCS projects to be candidates for the NER 300 award decision (4 UK projects, Belchatow CCS Project, Poland; Green Hydrogen The Netherlands; Porto Tolle, Italy and ULCOS-BF, France) and two projects were left in the reserve list (Getica CCS Demo Project, Romania and Peterhead Gas CCS Project, UK) [10].

5. Conclusions

- Many of the European countries made significant progress towards implementation of CCS technology through a national climate and energy strategy, research, transposition of the CCS Directive into national law and development of pilot and demonstration projects. However, the transposition process met various barriers and problems in a number of European States and the ongoing economic crisis presented challenges.
- By the end of 2011 the EC had confirmed the full transposition of the CCS Directive into national law only in Spain. However, by the beginning of 2012, an additional seven countries were considered by the EC to have successfully transposed the Directive (Denmark, the Netherlands, Italy, France, Lithuania, Malta and Slovenia). In spring 2012 other 12 countries (Austria, Bulgaria, Czech Republic, Estonia, Greece, Ireland, Latvia, Slovakia, Sweden, Portugal, Romania and UK) were waiting for assessment by the EC of whether the relevant national laws properly transpose the Directive. Two regions of Belgium, Croatia, Finland, Germany, Hungary, Poland and Norway continued their transposition process after March 2012.
- The countries with the most advanced level of CCS research and technology, CCS plans included in their energy and climate strategies, and which are supporting or planning to support pilot and demo projects (Germany, UK, Norway, France, The Netherlands and Italy) did not finish transposition before the EC deadline. Among these countries Italy, France and The Netherlands completed transposition at national level in 2011, while Germany and Norway postponed it to 2012. The situation in the UK regarding implementation of CCS is one of the most promising in Europe, considering the decision on governmental financial support of one billion pounds for demonstration projects published in December 2011 and several ongoing actions towards implementation of CCS technology in the country. However only offshore storage is likely to be permitted in the near future in the UK.
- The strong influence of Green parties and NGOs, and their ability to involve the public in debates, may have negatively influenced the transposition process in Germany, and may have contributed to a ban on onshore storage in Denmark until 2020, and abandonment of the plans for onshore demonstration projects in both Denmark (Nordjylland Coal Power Station) and Germany (Jänschwalde Lignite Power Station).
- Eight countries prohibited or are planning to prohibit CO_2 storage permanently in their territory, except for research purposes (Estonia, Ireland and Finland), or temporarily (Austria, Czech Republic, Latvia, Poland, and Sweden). Belgium, Greece and Italy do not permit storage in some selected areas, and Denmark banned onshore storage until 2020.

Several countries took measures to prohibit CO_2 storage temporarily in order to wait with large scale deployment of CO_2 storage technology in their territories (Austria and Czech Republic), or by limiting the amount of permitted for storage CO_2 (Bulgaria), and to see the results of the demonstration projects (Poland).

- In the studied countries CO_2 storage capacity was estimated as sufficient in 17 countries, insufficient in five countries, and no capacity was found in two countries (Estonia and Finland). No estimations are reported by Austria and Sweden.
- In summary therefore, it is clear that the speed with which the CCS Directive was transposed into national laws in the 26 studied European countries depends on different national conditions and problems, but does not directly correlate with national policy respect to CCS, financial situation or storage capacity. It seems that it is rather a specific combination of all these factors that influences the political climate in which such strategic decisions are to be taken

Acknowledgements

This research is supported by EU FP7 CGS Europe project (grant agreement number FP7-256725). We are grateful to all CGS Europe projects partners and their national contacts for providing necessary data and information. S. Holloway publishes by permission of the Executive Director, BGS (NERC).

References

[1] Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide and amending Council Directive 85/337/EEC, European Parliament and Council Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and Regulation (EC) No 1013/2006 (1). *Official Journal of the European Union* 2009; **L140**:114-35.

[2] Vangkilde-Pedersen T, Allier S, Anthonsen KL, Bossie-Codreanu D, Car M, Donda F, et al. FP6 EU GeoCapacity Project, Assessing European Capacity for Geological Storage of Carbon Dioxide, Storage Capacity, WP2, D16 report; 2009, http://www.geology.cz/geocapacity/publications.

[3] Armeni C. Case studies on the implementation of Directive 2009/31/EC on the geological storage of carbon dioxide. United Kingdom; 2011, www.ucl.ac.uk/cclp.

[4] Christensen NP, Holloway S, editors. Geological Storage of CO_2 from Combustion of Fossil Fuel. EU FP5. Summary Report. The GESTCO project; 2004, http://www.geus.dk/program-areas/energy/denmark/co2/GESTCO_summary_report_2ed.pdf.

[5] Piessens K. Quantifying the CO_2 storage potential in Belgium: Working with theoretical capacities. *Energy Procedia*, 2011; **4**: 4905-4912.

[6] Wójcicki A, 6th conference of Balkan Geophysical Society, 3-6.10.2011. New Data on CO_2 Storage Capacity of Poland, A05, 2011: 1-5.

[7] Norwegian Petroleum Directorate. CO_2 Storage Atlas Norwegian North Sea. 2011. http://www.npd.no/en/Publications/

[87] Randolph JB and Saar MO. Combining geothermal energy capture with geologic carbon dioxide sequestration. *Geophysical Research Letters*, 2011; doi:10.1029/2011GL047265.

[98] Krämer L. Case studies on the implementation of Directive 2009/31/EC on the geological storage of carbon dioxide. Germany. 2011; www.ucl.ac.uk/cclp.

[109] NER300 - Moving towards a low carbon economy and boosting innovation, growth and employment across the EU. European Commission, Commission Staff Working Document. Brussels; 12.7.2012, p. 1-19.