Opportunities for CO_2 Storage Pilot Projects across Europe

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CGS Europe
FP7 Pan-European Coordination Action on CO_2 Geological Storage

CO_2GeoNet
The European Network of Excellence on the Geological Storage of CO_2

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Preamble

In the field of the geological storage of carbon dioxide (CO_2), a 'pilot' project is one that has a research objective and where less than 100,000 tons of CO_2 are injected into the subsurface, typically over a few years. Although CO_2 Geological Storage (CGS) is well advanced from a technological point of view, research based on real field sites is now strongly needed in order to maximize the efficiency of these technologies, to optimize the tools needed for monitoring and verification, and to be able to adapt to the specificity of local geological conditions. Pilot projects can thus benefit investment decisions for deployment of CO_2 Capture and Storage (CCS) in the foreseeable future.

The CGS Europe Project consortium, involving 34 research institutes from 28 European countries (including the CO_2GeoNet Association), gathers together broad experience in many different fields of research related to CO_2 geological storage, as well as geological knowledge across the whole of Europe. A key aim of CGS Europe is to contribute to research and technological development of storage activities, in order to provide scientific knowledge to the authorities and the society in general, enabling policy makers and the public to have an informed opinion about the potential industrial development of CCS technologies.

In this context, the present CGS Europe report "Opportunities for CO_2 Storage Pilot Projects across Europe" provides an overview of the many potential pilot projects across Europe. Although currently still in the proposal stage, we take stock here of the wide range of scientific achievements that could be gained if some of the projects become a reality in the near future. CGS Europe hopes this work will contribute to building new knowledge on geological storage that can be used for the industrial demonstration and deployment of these technologies.

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Foreword

In June 2013, the Zero Emissions Platform (ZEP) published its report, "*Accelerating the demonstration of CO_2 geological storage in Europe – the case for up to six new storage pilots*".[1] This highlighted the need to establish a portfolio of large CO_2 storage pilots by 2016 in order to complement CCS[2] demonstration projects, accelerate state-of-the-art technology and increase public confidence in CO_2 storage. The report proposes criteria for such projects, as well as defining R&D deliverables.

In parallel, and in cooperation with ZEP's Taskforce Technology, CGS Europe has now conducted a pan-European questionnaire among its members in order to obtain information regarding potential projects. This work represents important input for developing such storage projects, but it is recognised that further opportunities may become available.

CGS Europe is a FP7 coordination action of the EC over 3 years (Nov. 2010 – Oct. 2013), with the objective of building a credible, independent, long-lasting and representative pan-European scientific body of expertise on CO_2 geological storage that will:

1. Instigate a durable networking of research capacity on CO_2 storage in all the relevant EU Member States and Associated Countries;
2. Liaise and coordinate its activities with other stakeholders and existing initiatives in Europe to help define and coordinate CO_2 storage research roadmaps and activities at national, European and international level;
3. Help reduce the existing gap between the 'forerunner' countries, where CCS activities have been started or planned, and those countries where these actions are not yet happening;
4. Contribute to the large-scale demonstration and industrial deployment of CCS;
5. Support the implementation of the European Directive on the geological storage of CO_2 and other regulatory regimes.

The CGS Europe Consortium involves 34 research institutes over 24 EU Member States and 4 Associated Countries. It has grown from the initial nucleus and experience of the CO_2GeoNet Network of Excellence,

[1] www.zeroemissionsplatform.eu/library/publication/224-storagepilotsreport.html
[2] CO_2 Capture and Storage

initially a FP6 EC-funded project (2004-2009) and now an independent Association under French law. The expansion of the membership of the CO_2GeoNet Association is currently underway with CGS Europe partners for enabling the durability of the consortium after the end of the project, and the further development of the representative reference body in Europe for authorities, regulators, industry and the public on scientific matters related to the geological storage of CO_2.

In this framework, it was considered very interesting to give all CGS Europe partners the possibility to give information about potential projects to be held in their home countries or surrounding regions. Therefore, a questionnaire was generated in order to be submitted to project partners, 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 situation is different in Member States, not only from a geological or economic point of view, but also in other aspects, like data management, public and private balance, CCS deployment expectance, etc. Therefore, questionnaires have been filled out in a different manner by participants and there is a dispersion of information. In any case, 22 proposals have been received in several Member States and Associated Countries and a very valuable set of information has been obtained.

This document provides not only the raw material of questionnaires but also an analysis of the information and the potentiality of it. It has to be pointed out that this is not an exhaustive work about potential pilot projects in Europe (there might be other options) but it can give a good overview of where, how and when it is possible to develop further experience around geological storage of CO_2.

Generation of the questionnaire

The first step in 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.

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

Note: This questionnaire could be complemented by any geological information that could be considered necessary for a better understanding of the proposed pilot.

Motivation for the development of Pilot Projects

CGS Europe and its partners are usually questioned about the difference between pilot scale projects and demonstration projects for Carbon Dioxide Geological Storage. From a formal point of view, pilot scale is linked to the amount of CO_2 that is injected onto the storage formation: Pilot scale is considered when the total amount is less than 100,000 tons of CO_2, being this number the threshold established in the European Directive for a mandatory application of storage permit. However, the difference is not only a matter of quantity.

Although carbon dioxide (or other fluids) injection is an activity that is already known, pilot projects are designed to obtain better, cheaper and more precise technologies related to exploration, injection, monitoring, completion of wells, etc as well as further research into geological storage. Pilots are necessary to keep research moving forward and are complementary to 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.

At the same time, pilot scale projects will be a powerful tool to enlarge and strengthen some industrial sectors that will be necessary for future deployment of CCS, such as geological consulting, drilling companies, geophysical execution and interpretation and laboratories. Pilots will also provide data for other technologies (geothermal energy, EOR, etc) …), like geological consulting, drilling companies, geophysical execution and interpretation, laboratories, etc. This is particularly needed in countries with low hydrocarbon resources where these sectors may not be as advanced.

It is already clear that CCS demonstration projects are not progressing as fast and effectively as initially planned when economic growth was greater. It should be made clear that the development of Pilot projects is not a substitution for demonstration – implementation at demonstration scale is still necessary. Pilot projects are the right field to investigate improvements in use of resources and technologies in demonstration and industrial projects. Investment made now in Pilot projects will save significant funds in the foreseeable future.

Public information needs to be transparent and widely distributed to engage communities in the deployment of low carbon technologies. A

widespread net of pilot scale projects will contribute to wider interest in CCS technologies and better access for the European society to technical, environmental and economic information. Approaching different communities and different countries through these Pilot projects will give also social researchers the chance to improve their capacities, reflecting the cultural diversity in Europe.

Last, but not least, integration of research and results within the EU can have a significant impact in the development of industrial processes and technologies all over the world. Pilot scale projects can give a new energy to this sector in Europe and provide a safer and more efficient deployment of CCS as a greenhouse gas mitigation technology in the upcoming decades.

Results summary

Before performing the analysis of the 28 pilot project proposals that were received, it can be noted that answers were also given by other countries, stating that at the moment, there are no possibilities to develop pilot projects in their territories, or addressing confidentiality issues which prevent them from making public these proposals. For different reasons, Germany, Slovenia and Croatia have announced non-availability of Pilot project proposals for this study. Actual project proposals received through this survey are described in the remainder of this section on a country by country basis.

Bulgaria

The University of Sofia proposes development of a project at the onshore saline aquifer of Pavlikeni. The storage formation, comprising mainly limestones and dolomites lies between 800 and 1,400 meters below the surface and is covered by a seam of marls. The site is close to Maritsa East power plants and therefore it could be combined with capture projects. The total estimated capacity of the aquifer is over 400 Mt, so the project could be upgraded to industrial scale if successful.

Unfortunately, there is no proposal of an R&D consortium that could develop the Pilot. Budget is not estimated either and therefore this proposal can be considered to be at an early stage and would need further preparation to become a concrete opportunity. If developed, it could be very helpful in supporting the deployment of CCS technologies in South Eastern Europe.

Czech Republic

The Czech Geological Survey (CzGS) proposes a Pilot project in a depleted oil field that could also be combined with studies of EOR techniques. The main storage formation is placed 1,600 meters below the surface and is formed of sandstones covered by impermeable clays. The pilot would include an injection of 20,000 to 40,000 tonnes of CO_2 into a sandstone deposit with an estimated capacity of 0.6 Mt.

The consortium proposed includes several Czech partners, including industrial members and also potential partners from Norway and Slovakia, leaving the door open to further cooperation from other CGS Europe partners. The project budget is proposed between 20 and 40

million Euros, aiming to receive support from the so called "Norway Grants". CO_2 could be supplied by a nearby biomass plant or by the chemical industry. This project is in its first stages but technically well advanced and could be soon ready to be developed.

Denmark

The Geological Survey of Denmark and Greenland (GEUS) proposes a research Pilot to take place onshore in Northern Jutland. Final location is still to be determined, although it is clear that the main storage formation will be in the sandstones of the Gassum Formation, under several caprock layers of shales and chalk. Depth of the storage formation at the site will be between 1,200 and 1,500 meters and its capacity will be large enough for several pilot proposals as it is estimated to be around several Mt of CO_2.

The consortium for this pilot project would be composed of partners from Denmark, Norway and Sweden, including research centres, universities and industrial partners. It is very likely that this project would operate in combination with other consortia related to geothermal energy production and a previous budget is under preparation. Although the project still requires definition of some funding schemes, this project can be considered to be in an advanced stage of preparation. GEUS supplied complementary information that can be consulted in the Annex to this report.

France

The proposal from France was submitted by IFPEN and BRGM and, although they originally proposed two different projects, as they had a lot of similarities they were finally merged into one project and research consortium. The site would be located in the Paris Basin and the main storage formation will be the Triassic (Keuper or Buntsandstein) or Lower Jurassic (Liassic) sandstones. It is proposed to inject several tens of thousands of tonnes of CO_2, with a maximum quantity of 0.1 Mt of CO_2 injected in total. Lessons learned from this pilot will be invaluable for precising the storage capacities of these formations, for which the theoretical potential in the whole Paris Basin has been assessed to thousands of Mt of CO_2, and for planning future CO_2 storage deployment schemes in the Paris Basin.

The consortium includes several partners from the French Scientific community and would be open to other research partners from abroad and to the industry at large. The final budget of the project is estimated to be around 50 M€. Early contacts with national agencies have been made to seek public funding.

This proposal is in an early stage of design but is building on experience gathered at basin scale and local scale in the context of previous feasibility studies, and therefore, it has a very solid basis. Moreover, an also very interesting point about the proposal in France is the possibility to combine storage research in this Pilot with other applications such as biomass plants and geothermal energy production.

Hungary

The Hungarian Institute of Geology and Geophysics (MFGI) proposes a research pilot to be developed onshore at a sandstone saline aquifer (1,500 meters depth) capped by clay and marls. Potential injection would be about 30,000 tonnes, having the possibility to upgrade the project, as volumetric estimations have reached to a potential capacity of more than 1 Mt of CO_2.

R&D consortium preparation is still in its very early stages, and there is the possibility to include industrial partners. There is also the possibility to obtain support from the state in order to fund the Pilot 20 M€ budget, in a project area with high rates of CO_2 emissions. There is the potential to combine this pilot with biomass plants and also the possibility of including geothermal energy in the project. This proposal is still being defined and needs further development but it could lead to public awareness about CCS in the region.

Italy

OGS provided a proposal for research of CO_2 geological storage in unminable coals, combined with an underlying saline aquifer, located about 1,000 meters deep in the island of Sardinia, although the potential storage can be prolonged under the sea bed, below a thick seal of siltstones and claystones. Pilot project is expected to inject a few thousands of tons in coal that can be extended to 500,000 tons in the subsequent demonstration phase.

The R&D Consortium is already working, involving several CO2GeoNet partners and has the support of governments of Italy and the Sardinia Region, aiming to create a large clean coal technologies centre ("Polo Tecnologico del Sulcis") The project is linked to an oxy-fuel capture power plant, having a total cost of circa 70 M€.

This proposal is well advanced and is not only supported by the research community and the decision makers, but also by the local population, as this area has been long time linked to coal mining and industrial activities, which may be partly re-activated through the new "Polo Tecnologico".

Netherlands

TNO has submitted three proposals for pilot injections in different geological and geographical settings: 1) in an offshore saline aquifer, 2) a pilot which is currently working in the K-12B offshore field and 3) in small depleted gas fields.

At the Q01 saline aquifer, TNO proposes a pilot (<100 kt) injection of CO_2 in the Vileland Sandstone formation, located between 1,300 and 1,600 meters depth. Overlying claystone facies of the same formation will be used as the potential seal. Estimated capacity of this aquifer is over 100 Mt, therefore, there is a chance for upgrading to industrial scale storage if successful. CO_2 for injection could come from capture facilities in Rotterdam, supported by the CATO Programme. Estimated budget is ca. 50 M€, and being an offshore site there are no specific impacts in local communities.

TNO also proposes to continue injection at the K12B site, a depleted gas field located below 3,000 meters depth. Already over 70 kt of CO_2 has been injected into the Rotliegend sandstone, sealed by thick salts. The total estimated storage capacity is 25 Mt and the budget of the project would be around 30 M€. One very specific issue that could be addressed is the possibility to test CO_2 transport by ship from the Rotterdam area to the injection site. A consortium including TNO, CATO and GDF-Suez is expected depending on the boundary conditions.

A third proposal with a very specific associated study is the seasonal storage in depleted or undeveloped gas fields in the Rotterdam area. The project is meant to investigate the potential for small fields to be

developed by using them for CO_2 buffer storage. This CO_2 could be seasonally supplied to greenhouses when needed, through connection to the existing OCAP-Pipeline. The seasonal storage would allow detailed study of the behaviour of reservoirs with multiple cycles of injection and production. These reservoirs are located between 1,200 and 1,600 meters depth and the total injected quantity would be several tens of kilotonnes. The estimated budget is 40 M€ and the use of CO_2 for geothermal purposes could also be addressed.

Norway

IRIS and SINTEF have delivered proposals for further developments in Norway, where geological storage is already underway and highly relevant (ongoing) experience is available in Sleipner and Snøhvit. These two projects are included in the questionnaire in order to remind the reader that CCS is already being undertaken. There is still the potential for cooperation with energy companies for EOR uses and maybe geothermal energy production, although this may be low efficiency.

Norwegian partners also propose a field laboratory in Longyearbyen, in a sandstone saline aquifer at relatively shallow depth (700 – 900 m) in a formation with small storage capacity. CO_2 could be potentially supplied from a nearby coal fired power plant. Although state support is indicated, no further information has been supplied.

Another field laboratory is proposed in Svelvik, with the goal of studying leakage. This field lab consists in a small injection (<200 tonnes of CO_2) in a very shallow (<100 m) unconsolidated sand with no sealing formation. State support is also assumed although no consortium is detailed.

Finally, Norwegian partners also point out the possibilities of a storage project linked to the Mongstad capture plant. Not many details are given but it is very likely that it could become a huge project offshore.

Poland

The Polish Geological Institute (PGI) submitted a pilot proposal at Dziwie, a Jurassic aquifer in Central Poland. This pilot uses the same aquifer as the cancelled project of Belchatow, which is a sandstone placed circa 1,250 m below the surface, which could be upgraded in the

future if demonstration possibilities rose again. Total injection planned is about 27,000 tonnes of CO_2 in a trap with a potential capacity of 1 Mt.

The consortium includes two R&D organizations and a drilling company plus an industrial CO_2 supplier. There is an approved budget of 19 M€ and it is very likely that the project could be combined with geothermal energy uses and biomass plants among the already arranged cooperation for the demo project. PGI is already the owner of the land where the project will take place.

Support from local authorities is a reality and was also being received from the national government, but late changes in the Ministries may also change the policy towards CCS. In any case, this project is very well advanced and has options to be combined with other possibilities.

Portugal

A proposal from Portugal has been provided by a non-CGS Europe partner (University of Évora) in cooperation with LNEG. Injection would take place in a saline aquifer located in a sandstone formation at an approximate depth of 1,600 meters. The seal is assured by a very thick evaporitic sequence. The proposed injection rate is about 10,000 tonnes per year although the total storage capacity estimated through screening formulae is at least 90 Mt, providing a potential for future upgrading to industrial scale.

The consortium needs to be completely defined although at least participation of LNEG and the University of Évora it is assured. There is the potential for cooperation with industrial partners as power plants and cement plants are located in the area, with regional emissions of 5 Mt per year. Implementation costs are estimated to be around 5 M€.

Although there is a political support for this injection proposal, contribution from the government is expected to be only in-kind. Therefore, the consortium needs to be enlarged with funding partners.

Romania

GeoEcoMar, the Romanian CGS Europe partner has provided four different proposals for pilot scale tests in this country. There are two

depleted hydrocarbon fields, one saline aquifer and one geological storage option potentially linked to Enhanced Oil Recovery.

At the Turceni site, storage is proposed in Triassic Sandstones, located 2,200 meters below the surface that are covered by thick shales. An expected injection of 100 kt of CO_2 could be also linked to oil recovery, using captured CO_2 from the nearby EC Turceni emission source. The consortium would include GeoEcoMar, Romgaz, OMV Petrom, ISPE and EC Turceni, supported by national and local authorities to supply a total budget between 20 and 40 M€.

Another possibility is provided at the Rovinari saline aquifer, where the injection of 100 kt of CO_2 is proposed in the Sarmatian sands, where the large capacity of the formation would allow upgrading to a larger demonstration project if such a proposal can be developed. The proposed consortium, budget and support is very similar to the case of Turceni given above.

A third option is available in the depleted hydrocarbon field of Samnic-Ghercesti, near Craiova, where Middle Jurassic reservoirs provide enough storage capacity to develop a pilot project in very similar conditions to the Turceni site, with the support of EC Craiova.

The last proposal from Romania is the depleted oil field of Galati, located at 2000 meters depth in a Pontian sand, sealed by marls. This project is supported by Arcelor Mittal and Steel Galati. There is a large storage capacity that could enable industrial projects in the future in this area.

Slovakia

The Slovakian Geological Institute Dionýz Štúr (SGUDS) has proposed 4 potential pilot sites for geological storage of CO_2 in Slovakia. There are three depleted hydrocarbon fields and one local aquifer. The first oil and gas field (Läb) is located at the Vienna Basin and the potential storage formation is about 1,400 meters below the surface. Expected injection is under 100,000 tonnes but total estimated storage capacity is over 2.5 Mt of CO_2.

At the moment, the R&D consortium is formed by SGUDS and Nafta, a private company with history of large-scale hydrocarbon exploration and underground storage. In the area there are also licenses for

geothermal exploration, a biogas station and agricultural greenhouses. Therefore, there is a high potential for cooperation with other initiatives. Furthermore, existing wells can be, at least partially, used for the project, limiting the budget to about 8 M€. On the other hand, no funding scheme is available in Slovakia and that could delay this project in the near future.

Two proposals are related to depleted gas fields in the Trans-Carpathian Basin (Ptruska and Stretava). There are several potential storage formations located between 1,000 and 2,000 metres depth. The structure of the consortium and potential advantages are very similar to those described at the Läb site, including potential combination with other industrial initiatives, but they also face the same lack of funding schemes and the difficulty of obtaining support from national or local authorities. In any case, these projects offer the additional incentive of continuing economic activities in areas with high unemployment.

Finally, there is also a proposal for the site of Marcelová in a closed saline aquifer with two potential storage formations (sandstones and limestones) at a depth between 1,000 and 2,000 metres. This site could have a storage capacity of circa 70 Mt and could be upgraded to industrial scale. A peculiarity of this site is that the aquifer is very rich in Odium and Brome and production of these very valuable elements could leave more space for CO_2.

The consortium includes SGUDS and Nafta and also a fertilizer industry that would supply CO_2 up to a maximum of 550,000 tonnes per year. Proposed budget is 25 M€ although there are also many difficulties in finding funds at a national level. There are also probable opportunities for cooperation with geothermal energy companies and agricultural uses of CO_2.

Spain

The City of Energy Foundation (Ciuden) proposes to continue to support the pilot site of Hontomín, already included in the first pilots supported by the EU. Hontomín has been redefined in the last few months and field operations have already been started, taking into account potential cooperation with the demonstration project of Endesa to be held in Spain in 150 km distance from Hontomín.

Hontomín storage formation is a limestone located 1,600 metres deep and a large share of its 30 M€ budget has already been invested in geophysics and drilling operations. CO_2 injection will start by the end of 2013. Ciuden is planning further experiments as Hontomín can be considered as a well advanced Pilot operation with opportunities for research.

Sweden

A common initiative between Swedish and Finnish partners has generated a new research project: BASTOR (Baltic Storage of CO_2). Its final goal is to locate a suitable site for a pilot injection in a Cambrian sandstone saline aquifer. Although the site is not known yet, it will be located offshore, but depth and injection rate still need modelling activities to be determined.

Swedish (University of Uppsala, Chalmers) and Finnish (GTK, VTT) partners are already developing the project, but it is expected to involve also partners from Poland, Denmark and Latvia. Industry involvement (power, steel and oil sectors) is also being sought; taking in account some Swedish companies are already supporting the project. Global CCS Institute also gives advice to current research.

Governments of Finland and Sweden are already supporting on-going research activities and additional efforts are being undertaken in order to achieve further regional support.

Turkey

The Middle East Technical University (METU-PAL) points out there is an ongoing EOR project for research in Turkey. In any case, the main operator is TPAO, the main oil and gas company of the country and data remains confidential. Therefore, no further comments can be provided.

United Kingdom

The British Geological Survey (BGS) proposes two initiatives in the UK. The first one is an onshore saline aquifer, located in the Sherwood Sandstone Group, a largely known aquifer. This area has been previously studied and some small oil fields are located there, proving

availability of seals. Potential injection might be in the tens of kt, provided expected closures are quite small.

A mixed public – private consortium is proposed, although industrial funds need to be sought, as state support is devoted to the CCS competition and only mainly regulatory for other purposes. There is an experimental capture plant in the surrounding area (100 tons/day) and the expected budget is higher than 1 M£ but not defined. This project can provide MMV knowledge through a pilot experience that can not be carried out offshore because of the large costs.

The second proposal from BGS is located offshore and it is not a regular storage pilot, but an experiment to measure potential impacts of a CO_2 release through unconsolidated marine sediments in the sea bed. The proposal is located in the sea loch of Scotland and consists on controlled releases of CO_2 in marine sediments, 12 meters below the sea bottom, located under 12 meters of water column.

There is a large and strong research consortium composed of Japanese and UK Institutions that have been studying migration through sediments since 2010. The proposed budget of this project is 1.5 M£ and the population of the area is supportive to this activities.

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 different types of storage formation (saline aquifers, active hydrocarbon fields, depleted hydrocarbon fields), therefore making available the improvement of technologies under different conditions. We need to note 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 is also available from the point of view of geological setting. Proposals are provided in sandstones, sands and carbonated rocks, even coal, 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 in the onshore, providing examples closer to the affected communities, there are also offshore proposals.

The geographical distribution of the proposals is well balanced in 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.

CGS Europe partners have reported a general lack of funding schemes to develop these projects. In this aspect, the 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 the present lack of a viable self-financing model for geological storage. 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 considerably 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 industrial sectors, in some cases supported by national and local authorities. Continued progression 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 (see Table 1) that have been provided to this report, it can be concluded that CGS Europe – CO2GeoNet is in a very good position to provide support 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 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
Italy	Sulcis	Onshore/offshore	Coal + Aquifer	1000	Coal	70 (incl. capture)
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
Sweden	Bastor	Offshore	Aquifer	>800	Sandstones	
Turkey		Onshore	EOR			
United Kingdom	UK on	Onshore	Aquifer	800 - 1200	Sandstones	>1
United Kingdom	UK off	Offshore	Field lab	12	Sediment	2

ANNEX: COMPLETED QUESTIONNAIRES

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 CO2 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.

PROJECT DESCRIPTION OF "CO2 INJECTION PILOT SKAGERRAK"

Introduction

Tel-Tek, the University of Oslo and GEUS conducted in the period 2009-2011 along with other partners two parallel projects on CCS potential in the Skagerrak Kattegat area. One of the projects was funded by Interreg while the other project was funded by the Norwegian Climit programme and industry partners. These two parallel projects were concluded in December 2011 and the results were summarized in a report: "Carbon Capture and Storage in the Skagerrak / Kattegat - Region". This work provides the scientific basis for this project proposal.

The previous projects looked at both CO2 sources/capture, infrastructure and geological storage. The geological storage work package focused on finding out whether formations and structures to store CO2 could be found in this geographical area. Existing seismic data, well data and other geological information were studied and analysed. This work concluded that the Gassum Formation in Skagerrak may be suitable for CO2 storage.

To eventually qualify the Gassum Formation for CO2 storage, more detailed studies and analyses of the formation and the cap rock (the Fjerritslev Formation) are required. The Gassum Formation is widely and continuously distributed in most of the Norwegian-Danish Basin , and is found in many wells offshore in Skagerrak area and onshore over large parts of Denmark and South-western Sweden. In the new project which is further described in this document, we propose to test the injectivity of the Gassum Formation onshore, thus being able to pre-qualify the formation for offshore CO2 storage. This new project is divided into 3 phases :

1) a feasibility study,
2) a planning phase with most likely water injection in an existing drilled well, and
3) an injection phase with drilling and injection of water and CO2.

The feasibility study phase is now on-going. Part of the work will be to establish a broader consortium of industry and research partners for the next phases and also to anchor the work by national authorities in Denmark and Sweden.

We will also point out that the work which will be proposed as an outcome of the feasibility study will contain important elements of a generic nature and also transferable to other pilot projects.

About the project

The injectivity of a reservoir or a reservoir interval is a critical parameter when it comes to assessing if the structure would be suitable for CO2 storage. Poor injectivity would require a high injection pressure to inject sufficient amounts of CO2, and may cause

fracturing in the cap rock with possible subsequent leaks. Injection rate is thus entirely dependent on injectivity. It is possible to obtain much information about the injectivity of CO2 by performing water testing, and by using phase equilibrium data to calculate the injectivity of the various fluids. The injectivity of CO2 in several pilot projects have proved to be a problem, so it is important to have empirical data from reservoirs that are located at different depths. In addition, different depositional environments and diagenetic alteration could give very different reservoir response to injection. By testing reservoir sandstones like the Gassum Formation at different depths, good injection data can be obtained and we can also be able to better predict injection properties in areas where well information is missing, as in the Skagerrak offshore area.

The on-going feasibility study considers where and how injection tests could and should be done. In addition the project also evaluates how injection can be performed in a safe and efficient way at a minimum cost. Injection tests in wells onshore in Denmark and southern Sweden will be relatively inexpensive compared to offshore drilling in the Skagerrak area and this is the main reason to propose onshore injectivity tests at this stage. Also, the Gassum Formation is assumed to be relatively homogeneous over most of its distribution area in this region.

The 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 CO2 injection and monitoring. More detailed mapping of the reservoir rocks to obtain better estimates of safe pressure and the number of wells needed, will also be considered. This could also provide a better estimate of CO2 migration in the reservoir when injecting offshore.

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 (biofuel or biomass heat plant) * 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 (see list of members on next page)
CLOSE EMMISSION SOURCES	Bio-fuel plant or biomass heat plant for the pilot stage Le Havre 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
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 – expected start January 2013 (storage as dissolved CO2, combined with brine production – injection & production doublet)
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	YES! It is the purpose of this pilot and of a previous research project in this geographical area co-funded by Region Centre (project CPER ARTENAY) and 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 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 location, and previous CO2 storage and geothermal research projects targeting the same Triassic reservoir nearby, These previous projects were supported by ADEME, Region Centre, FEDER, etc.

* **Geodenergies** – Research Institute of excellence for decarbonised energy focused on geotechnologies: CO2 storage, geothermal energy end energy storage

Public Partners	**Private Partners**
BRGM, CNRS, INSU, CSTB, IFPEN, IFSTTAR, IPGP, MINES PARISTECH, UNIVERSITE ANTILLES GUYANE, UNIVERSITE LORRAINE, UNIVERSITE ORLEANS, UPPA	ACTYS, AIR LIQUIDE, ALCEN, BUREAU VERITAS, CEMENTYS, CFG SERVICES, CGGVERITAS, DRILLSCAN, ECOGEOSAFE, ELECTERRE DE France, ENEA CONSULTING, ENERTIME, ENTREPOSE CONTRACTING, FONROCHE GÉOTHERMIE, GDF SUEZ, GEOGREEN, GEOSTOCK, GEOTHERMIE BOUILLANTE, HINICIO, KAPPA, NOSOCO.TECH, POLE DE COMPETITIVITE AVENIA, POLE DE COMPETITIVITE S2E2, SOLEXPERT, TOTAL

****CO_2GeoNet Association -** The European Network of Excellence on the Geological Storage CO_2

Current membership:

- GEUS (Denmark)
- BRGM (France)
- IFPEN (France)
- BGR (Germany)
- OGS (Italy)
- URS (Italy)
- TNO (Netherlands)
- IRIS (Norway)
- NIVA (Norway)
- SPR Sintef (Norway)
- BGS (UK)
- HWU (UK)
- IMPERIAL (UK)

NAME OF SITE - SULCIS	
COUNTRY	ITALY
TYPE OF STORAGE	UNMINABLE COAL (Produttivo formation) and underlying SALINE AQUIFER (Miliolitic limestone)
LOCATION (ON/OFF)	ONSHORE, in the Sulcis coal basin (South-West Sardinia island, Italy), with extension OFF-SHORE
DEPTH TO TOP OF STORAGE FM	In the considered area: 900 m (Produttivo) and 1000 m (Miliolitic limestones)
STORAGE FORMATION LITHOLOGY	Produttivo: 50 to 80 m thick, coal beds, limestone, sandstone and claystone Milioloitic: 30 to 100 m thick, bio-calcarenites maris
SEALING FORMATION LITHOLOGY	Cixerri formation: 300 m of polygenic conglomerates, sandstones, siltstones and claystones
STORAGE REQUIREMENT (PILOT)	Some thousands t CO2 for the pilot and up to 500.000 t/y for the demo, starting from 2016
ESTIMATED STORAGE CAPACITY	The GeoCapacity project has evaluated a storage capacity of 70 to 190 Mt of CO2 in the whole Sulcis coal basin (on-shore and off-shore). Regarding on-shore, more recent and conservative evaluations bring the total to about 30 Mt of CO2.
POTENTIAL R&D CONSORTIUM	After GeoCapacity, a new evaluation of the ECBM and CO2 geological storage potentiality in the Sulcis basin has been started by a consortium formed by the

	following CO2GeoNet members: OGS, BRGM, IFPEN, TNO, Imperial College and university of Rome La Sapienza. This project is still running and, through high-resolution reflection seismic surveys, deep drilling and coring, lab measurements and geological modelling, will better image the subsurface and constrain more precisely the storage potentiality in the coal and in the underlying saline aquifer. University of Cagliari, Sotacarbo (Research Center on Coal Technologies), RSE SpA (Research on Energy Systems) and ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development) contribute to this research.
CLOSE EMMISSION SOURCES	The CO2 needed for the pilot will come from the project "Polo Tecnologico del Sulcis". One of the planned activities is the construction of a oxy-combustion pilot power plant of approximately 50 MWt, which will be completed by innovative infrastructures for CO2 capture. Following this first phase, a 350 MWe demo plant will be realized, equipped with about 80 MWe equivalent CCS components.

PROJECT BUDGET	30 M€ for the oxy-combustion 50 MWt power plant, supplemented by 9 M€ from the Sardinia Region, in three years. 3 M€/year for 10 years, for the other activities of the project "Polo Tecnologico del Sulcis": development of pre- and post-combustion techniques for CO2 capture and setting-up of a pilot site for the geological storage of CO2 in coal and underlying saline aquifer. Then 600 M€ in 10 years for the demo plant.
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	See above
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	Not considered
POTENTIAL COMBINATION WITH BIOMASS CO2 CAPTURE	Not considered
POTENTIAL COMBINATION WITH CO2 USES	Not considered
STATE SUPPORT	On December 2012, the Italian Ministry of Economic Development (MISE) and the Sardinia Region have signed a Memorandum of Understanding for joint of actions aimed at creating new employment opportunities in the Sulcis area, among which the "Polo Tecnologico del Sulcis", a Center of Excellence on Clean Coal Technologies. This Center will develop and test new capture techniques and set up a pilot test site for geological storing of CO2 in

	coal and aquifer, in the Sulcis area.
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	The area has a long history of coal mining and is suffering a long period of de-industrialisation. The Memorandum of Understanding aims at inverting this process and create new job opportunities in the Sulcis region, in sectors of national interest.
COMMENTS	Due to the long tradition in coal mining (Sulcis hosts the only still active coal mine in Italy), the local population is not against pilot tests of CO2 storage in the Sulcis territory. Moreover, an important characteristic of this pilot project, is the plan for extending it to a full demo project in a following phase.

HUNGARY	
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 CO2/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 is

CAPTURE PROJECTS	reduced only at the pressuring of CO2
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 CO2. In the other words – exploitation of aquifer may release a space for CO2.

BASTOR (**BA**ltic **STOR**age of CO_2)	
COUNTRY	Baltic Sea Region (Sweden/Finland/Lithuania/Poland/Russia)
TYPE OF STORAGE	Saline aquifer
LOCATION (ON/OFF)	Offshore
DEPTH	>800 metres
STORAGE FORMATION LITHOLOGY	Cambrian sandstone
SEALING FORMATION LITHOLOGY	
STORAGE REQUIREMENT (PILOT)	< 100 000 tons
STORAGE CAPACITY	t b d, dynamic modelling in progress, it is expected that large scale storage could be developed
POTENTIAL R&D CONSORTIUM	A Baltic Sea region initiative, currently involving research institutions and geological surveys in Sweden (Uppsala University, Chalmers) and Finland (VTT, GTK). Potentially, Poland (AGH-Krakow, PGI), Latvia (Riga University) and Denmark (GEUS) could take part. Power, Mineral, Steel and Oil industry are natural project partners. The Global CCS Institute (Australia) is supporting the current research and would be invited to provide continued support.
CLOSE EMISSION SOURCES	HeidelbergCement, Slite, Sweden, Neste Refinery, Finland, SSAB steel mill Oxelösund, Sweden are partners to the current project and are expected to extend their support for a pilot project
PROJECT BUDGET	To be elaborated during Q1 2014
POTENTIAL COMBINATION WITH CAPTURE PROJECTS	See above (sources)
POTENTIAL COMBINATION WITH GEOTHERMAL ENERGY USES	None
POTENTIAL COMBINATION WITH BIOMASS CO_2 CAPTURE	Long term, Swedish and Finnish pulp and paper industry.

POTENTIAL COMBINATION WITH CO_2 USES	The potential location is adjacent to current oil and gas production where EOR could materialize.
STATE SUPPORT	Efforts to address regional, (Baltic Sea region) support (HELCOM?). Finnish and Swedish governments currently support on-going CCS programs and continued support appears likely as process industry provides significant share of both countries' GHG emissions
SPECIFIC BENEFITS FOR LOCAL COMMUNITIES	The Baltic Sea region accounts for a gross annual emission volume of 250 million tons. Cost efficient CO_2 management would economically benefit the region's industry and hence provide a long term platform for a sustainable and competitive base industry. In addition, substantial volumes of CO_2 are emitted from the region's pulp and paper industry, which could support the development of negative emissions. The Gotland Region is already a stakeholder in the Bastor2 project and dependent on CCS implementation for its emissions intensive mineral industry.
COMMENTS	This is a joint Swedish and Finnish initiative, formed on more than three years of collaborative CCS research. The currently on-going geological research will result in a substantive report later this year. This is a unique project in that it incorporates detailed geological information from four countries, with territories bordering to each other in the south east of the Baltic Sea. The intentions of the current consortium are to form a regional consortium, potentially building on the consent of the Council of the Baltic Sea States, thereby forming a very strong political platform for the venture.

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 BIOMASS CO2 CAPTURE	Compostilla experimental plant of capture also works with biomass.
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 offshore	
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.

CO_2GeoNet
The European Network of Excellence
on the Geological Storage of CO_2

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