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The EU Geocapacity Project - Saline aquifers storage capacity in Group South countries

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Abstract

The EU Geocapacity Project aims to obtain an estimation of the potential capacity of CO_2 storage in deep saline aquifers, depleted hydrocarbon fields and coal beds in Europe. Prior to this project, the availability of data to calculate the storage capacity differed very much in each country. Some of them have already provided estimations for CO2 storage capacities in the framework of previous projects (e.g. GESTCO (FP5) and CASTOR (FP6)), while other countries have not been evaluated at all. Therefore, an important part of the work performed in the frame of the GeoCapacity project has been to homogenise estimation methodologies and reliability of data. Emphasis has been placed on the study of saline aquifers, as this type of geological formation, was until now, the less studied and most poorly understood compared to the depleted oil and gas fields. The work activities were organized in geographical groups to make them easier to manage.

The Group South is composed of four Mediterranean countries: Spain, Italy, Slovenia and Croatia plus Bosnia - Herzegovina. Specific methodologies were adopted in order to achieve different goals:

- Creation of maps of regional storage potential
- Collection of geological information of storage sites
- Estimation of storage capacities
- Elaboration of databases to be inserted into GIS
- Detailed analysis of case studies and scenarios for economic evaluation
- Integration of the storage capacity data with emission sources and pipeline infrastructure

Each of the countries belonging to Group South worked and continue to work in order to achieve such goals, despite of their different geological settings. The initial phase of such analyses included mapping of regional aquifers and locations of possible storages and seals described using data from hydrocarbon or water exploration, represented by borehole data and seismic surveys. Later on, structures contained in these aquifers were studied and

CO_2 storage capacity estimated with a higher precision. The two most promising or best defined structures in every country have been selected for a more detailed study.

As a result of this project, it can be observed that CCS can play an important role in Mediterranean countries, as part of their strategy to mitigate GHG emission. Storage efficiency factor determination is the key issue, and also further exploration for new data.

Keywords: Geological Storage, CO_2, capacity estimation.

1. INTRODUCTION

In the EU GeoCapacity project, regional assessment of geological storage capacity is being done for almost all European countries. The country partners have been grouped geographically, hoping that there would be enough geological similarities in the basins pertaining to the neighbouring geotectonic units to allow meaningful comparisons of results. Group South encompassed two small countries (Croatia and Slovenia) that have already made some preliminary estimates in the CASTOR project WP 1.2, and two large countries where these studies have just been initiated in the frame of the GeoCapacity project (Italy and Spain). An emission inventory was the first thing done in each country belonging to Group South, to define the needs for geological storage capacity (Table 1). The study of the geological settings was also performed by each partner, with the aim of obtaining a unified way of estimating the effective storage capacity. This led to the production of maps for different types of geological storage units: HC fields, regional saline aquifers and coal beds. As expected, large differences in estimated capacity resulted (Table 1) but generally the largest capacities were estimated in the regional aquifers, defined as "porous and permeable basin-wide sedimentary bodies saturated with brine"

Table 1. Large industrial CO_2 sources and potential geological storage objects

	Emissions inventory		**Storage capacity estimates (Mt CO_2)**		
	No. of sources (≥ 0.100 Mt/yr)	Their total emissions (Mt/yr)	Depleted HC fields	Regional aquifers	Coal beds
Spain	227	151.5	35	14,300	~200
Italy	247	212.1	n/a	?	?
Slovenia	7	7.4	2-6	50-200	Some potential
Croatia	8	6.2	190	4,900	?

2. COUNTRY EMISSIONS

Despite a country's emissions, statistics usually take into account other Greenhouse Gases other than CO_2 and also all types of CO_2 sources. The GeoCapacity Project decided to include in its databases only those stationary sources susceptible to becoming industries where CO_2 can be captured and eventually stored. Minimum emission considered in this case was 0.1 Mt of carbon dioxide per year. As a whole, the four Mediterranean countries of Group South accounted a total emission of over 377 Mt per year, based on 2006 reports. Obviously, larger and more populated countries are also those with more industrial sources and higher emissions.

The database compiled in the framework of the GeoCapacity project includes not only information such as the amount of CO_2 emissions and the geographical position of the source, but also data including: the expected power plant lifetime, its main fuel and type of facilities. This information is also complemented with data on existing pipelines in each country, which can be used as a pathway for future CO_2 transportation. In this way, it is possible to classify the main CO_2 sources in relation to possible sinks and to establish how a network of carbon capture and storage (CCS) could be implemented in Europe.

3. MAPS OF REGIONAL STORAGE CAPACITY

Before a detailed study of geological storage sites can be done, a country wide analysis of geological formations that could be used as potential reservoirs has been considered. The upper boundary of these formations should be placed at a depth higher than 800 m, in order to maintain the CO_2 supercritical state. A sealing upper formation has also to be present. Formations with high potential are those with a high secondary porosity such as sandstones and carbonates, while sealing formations should be clays or marls.

Each country of the group has faced different challenges to produce these maps, mainly related to the different geological settings and to variations in the amount and quality of available data. For example, Spain is a country characterized by the occurrence of huge sedimentary basins, while geophysical and deep borehole information are poor (as oil and gas exploration was unsuccessful). Therefore, most estimates were performed at a regional scale. With regards Italy, although the extension of the sedimentary basins is more limited, the amount of the available data from oil and gas exploration is large compared to other countries and, therefore, estimations have to be developed more locally and site by site. However, we have tried to compare the results we have obtained through adequate assumptions in using the formulae proposed for the capacity evaluation (Dallhof et al., 2007).

For the deep saline aquifers, the formula is the following:

$$MCO2e = A \times h \times \phi \times \rho CO2r \times Seff \quad \textbf{(1)}$$

where:

- $MCO2e$ – effective storage capacity (t)
- A – area covered by regional aquifer (m^2)
- h – average height of aquifer × average net to gross ratio (m)
- ϕ – average reservoir porosity (%)
- $\rho CO2r$ – density of carbon dioxide at reservoir conditions (t/m^3)
- $Seff$ – storage efficiency (% of pores expected to be filled with carbon dioxide) (-)

Using an average storage efficiency of 2% (a number that was agreed within the EU GeoCapacity project), the estimations obtained for different basins sum up to 14.5 Gt. The main results obtained by the country partners are described below:

In a wide range classification, the peninsular territory of **Spain** is divided into three great zones:

- **Iberian Massif**. It covers the Western part of Spain and almost the whole territory of Portugal. It comprises Paleozoic materials that have been affected by Hercinian tectonics. There is a large amount of igneous and metamorphic rocks in this area, along with faults, steep folding and compression. As a region it has been discarded as a potential storage for CO_2.
- **Alpine mountain ranges.** There are three different mountain chains that formed during Alpine movements. The Pyrenees and Cantabrian Mountains in the North with an E-W strike, the Iberian Mountains in central Spain with NW-SE strike and the Betican Chain on the Mediterranean coast with a SW-NE strike. Depending on the location within these mountain ranges, we find formations and structures that aresuitable for CO_2 storage, especially sandstones and karstic carbonates.
- **Cenozoic Basins.** Deposits within these basins are significantin the areas of great Iberian rivers (Ebro, Tajo, Duero and Guadalquivir). Thickness of sediments in some areas is over 5,000 m, and includes deposits of sands, sandstones and karstic carbonates filled with salty water. These basins have been explored by oil and gas companies, although this exploration has been mostly unsuccessful.

Despite extensive exploration efforts made over decades, especially between 1960 and 1990, Spain is a country with very little oil and gas resources. This is why most of the potential storage is in the form of saline aquifers, and very locally, coal seams. Most important coal basins are found in the North West, and their storage potential has been estimated in the region of 200 Mt.

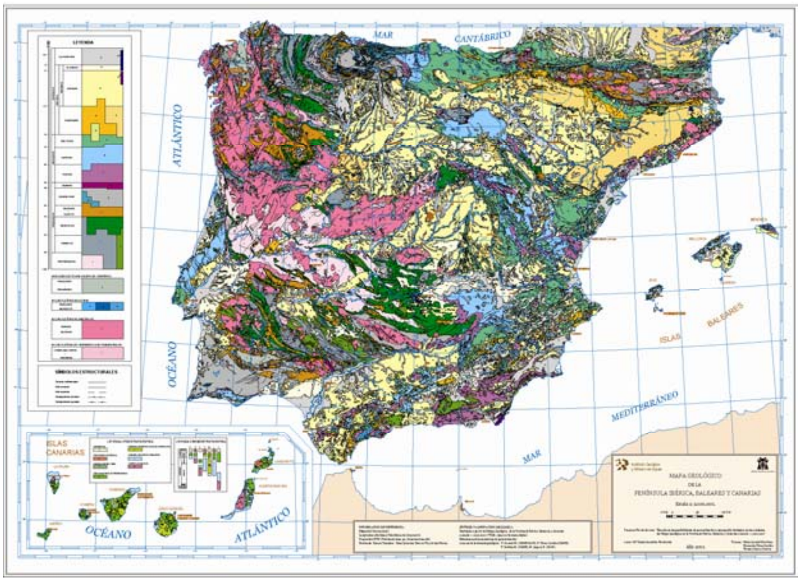

Figure 1 Geological map of Spain at an original scale of 1:2,000,000 (IGME, 2004)

In over 55 years of intensive exploration for oil in **Croatia**, more than 60 significant hydrocarbon accumulations were discovered, mostly in the SW part of the Pannonian basin, but also in the Northern Adriatic off-shore (Fig. 2, Saftic et al., 2008). These were all small or medium-sized fields, and many, especially oil fields are near depletion. The knowledge acquired from exploration work is now an important asset for the study of potential geological storage of carbon dioxide. There are two regions with significant potential – the Southern part of the Pannonian basin and the Adriatic off-shore. TheDinaric area is not considered as having storage potential due to deep karstification of carbonate formations (down to 1000 m) and pronounced seismic activity.

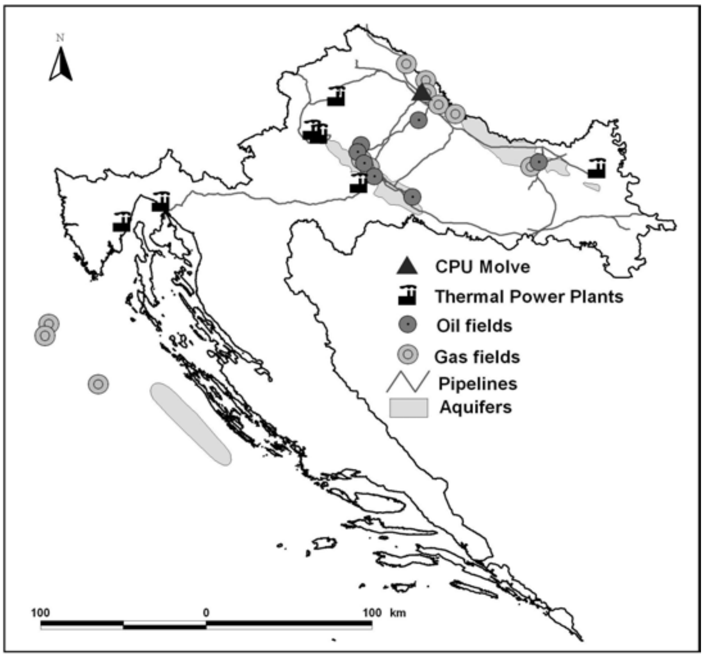

Figure 2 CO_2 point sources, major pipelines and potential geological storage objects in Croatia (Saftic et al., 2008)

By far the largest storage capacity is estimated in regional saline aquifers (Table 1) while capacity in HC fields is in second place. Aquifers were assessed based on the regional geological subsurface maps (Saftić et al., 2003) and by extrapolating reservoir properties from oil and gas fields where known. Effective geological storage capacity in these formations was then calculated using the formula above with a storage efficiency of 3% (note that several structural closures were drilled therein finding only saline water). Capacity estimates if HC fields are based on the volumes produced and substantiated with much more detailed estimates of reservoir geometry and reservoir properties. No estimates were made for the coal layers because data on the deep coal seams are not available.

In the case of **Italy**, some new issues have to be assessed. For example, the country is characterized by a general high seismic risk; therefore, only areas where seismic events of magnitude < 4 have been recorded will be considered. Another important factor is heat flow, which can be really high in some parts of the country. That is not the case in the area known as Bradano Foredeep, one of the most promising localities, owing to the high quality of the potential reservoir and caprock.

The map shown in Figure 3 highlights the location of possible sites for CO2 geologic storage in Southern Italy (yellow shaded areas); green and red dots indicate the location of wells drilled by oil companies since 1950 (green: data available, red: data not available). The location of seismic lines collected both on- and offshore is also indicated. The Basilicata 1 shaded area is located within the Bradano foredeep. Other potential areas located in offshore basins have been also identified. The capacity of these potential reservoirs is at present still under evaluation.

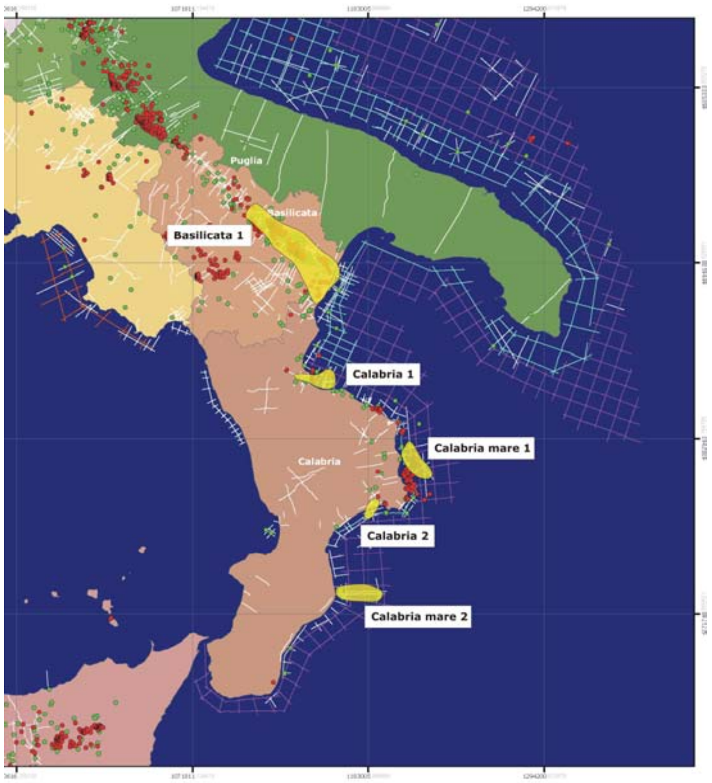

Figure 3 Map of most promising areas for geological storage in Italy (Donda et al, 2008)

In the case of Slovenia, very little reliable data is available, although some potential storage locations in aquifers have been located. These are found in: the Ljubljana basin, the Celje basin, in the Slovenian part of the Pannonian basin and in the SW Flysch basin. Sedimentary rocks that can be found in the appropriate depth range for CO_2 storage are abundant in the country, although the geological structure is complex and requires further study. Extensive targeted exploration will be necessary to better evaluate the storage potential in aquifers. Furthermore, potential storage in unminable coal layers deserves additional attention. Main Slovenia sources and potential storage possibilities are presented in Figure 4.

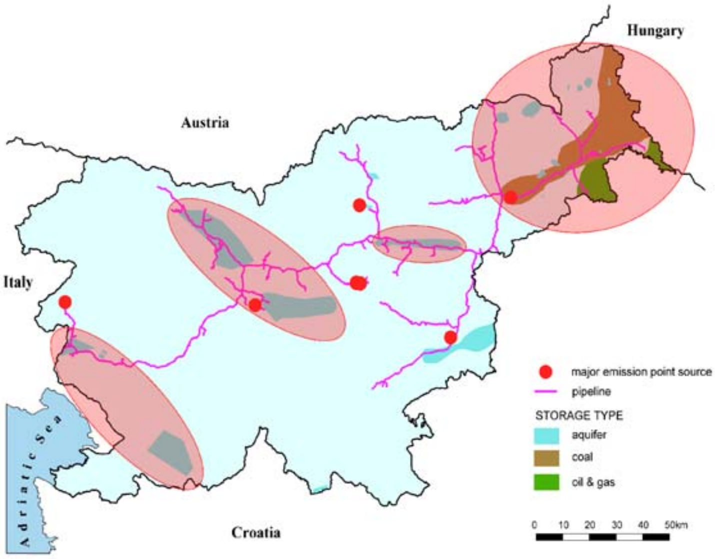

Figure 4 Main sources and possible sinks in Slovenia. (Car, 2008)

4. CASE STUDIES

Each of the countries participating in the GeoCapacity Project has assessed two specific case studies within their national boundaries. In the case of Group South countries, there are five potential storage sites in saline aquifers and three in oil fields. These case studies have been identified based on more detailed analyses on specific areas with higher levels of information and good prospects in terms of CO_2 storage. The sweep efficiency factor can be, in some cases, higher and more accurate at these sites, due to the better knowledge of key parameters, such as the pressure transmission to the nearest aquifers. Links between sources and sinks are described and an economical study of different CCS scenarios is ongoing. Here we summarize the main characters of one test case for each country, as recently described by Saftic and colleagues (2008). However, it is important to highlight that this analysis will not be finalized until December 2008.

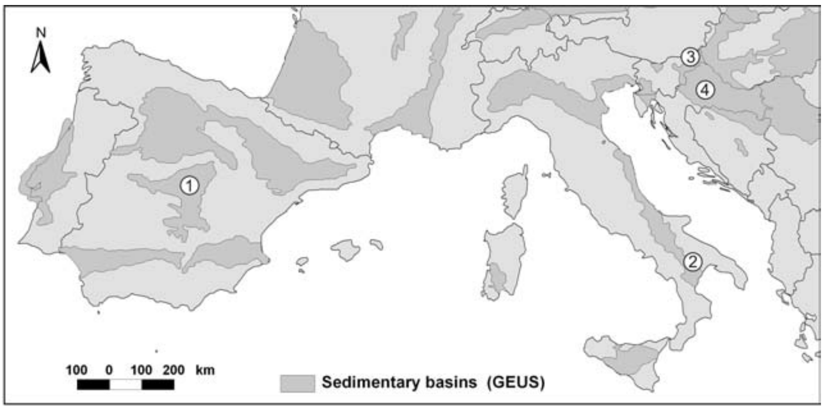

Figure 5 Case studies in Group South countries: 1 – Tielmes, 2 – Bradano, 3 – Pecarovci-Dankovci, 4 – Ivanić. (Saftic et al, 2008)

Tielmes is a double-domed anticline situated in the Eastern part of the Madrid – Tajo Basin. Two formations have been identified as potential storage formations.These are Utrillas and Buntsandstein, both are sandstones, although the prior is Lower Cretaceous and covers the whole structure, whereas the latter formation is Lower Triassic and only present in the Eastern dome. Total capacity estimated using a 10% storage efficiency factor is 800 Mt of CO2.

The **Bradano foredeep** is a NW-SE oriented basin lying above a Mesozoic carbonate platform, which is subducting towards the SW. The potential reservoir is a part of this basin's infill, it consists of sand with some thin clay layers, and is Upper Pliocene in age. It represents a confined aquifer, as it pinches out against the carbonate platform towards the East, whereas towards the West it deepens below the allochthonous unit of the Appeninic front. Some questions relating to effective porosity, permeability or trap structures are still to be answered, hence the storage efficiency factor used in the calculation of the potential storage capacity of this site was 2%, which produces a potential capacity of CO_2 storage estimate of 360 Mt.

The case of **Pecarovci – Dankovci** is an antiformal structure with an extent of 2-5 km2 that was identified with geophysical investigations in the 1977-1990 period, when several boreholes were drilled and tested. Based on the data obtained it can be suggested that CO_2 could be stored within several layers in the depth range of 1000-2000 m. The most important reservoir rocks are Miocene sandstones, siltstones and conglomerates, along with Mesozoic dolomites and breccias. In this case, a first estimate of 5 Mt potential capacity has been obtained.

The **Ivanić** oil field was discovered in 1963, when oil was found in multiple thin-layered Upper Miocene sandstones with porosity of 21.5-23.6% and permeability of 14.6-79.6 mD. An interesting model of production and storage in two phases has been developed, in order to calculate possibilities not only for CO_2 storage but also potential secondary recovery of oil. Though storage capacity is limited in the oil production phase, this is an early opportunity to start injection of large masses and to test the reservoirs "close to the full scale". CO_2 retention capacity in EOR phase is estimated to be around 1.45 Mt of CO_2 during the 25 years of injection and production.

5. CONCLUSIONS

The main conclusion derived from Geocapacity Project activities in Group South is that CCS can be considered as a serious option for Greenhouse Gases emission mitigation, as the geological settings within the country partners are suitable for the geological storage of CO_2. However, regarding Group South, each country needs to obtain crucial data, (i.e. physical parameters, accurate geometrical description…), before the real storage units are implemented. Data acquisition and an accurate calculation of the storage efficiency factor are common issues to Group South countries.

Although the highest storage potential can be found in Spain and Italy, due to larger extensions of their sedimentary basins, Slovenia and specially Croatia present some interesting cases for pilot and demonstration tests. However, if one also considers a country's annual CO_2 emissions and infrastructure availability, even lower potential storage volumes become interesting. The GeoCapacity project has been able to supply the first evaluation of the potential capacities in each country, and this represents the "start line" of further investigations. Economical studies on the feasibility of CCS in each country are at present being developed and they will provide a further step in obtaining accurate estimates of the geological storage potential of each country.

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