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available at http://www.entek.chalmers.se/~anly/symp/symp2001.html

ASSESSING EUROPEAN POTENTIAL FOR GEOLOGICAL STORAGE OF CO_2

FROM FOSSIL FUEL COMBUSTION

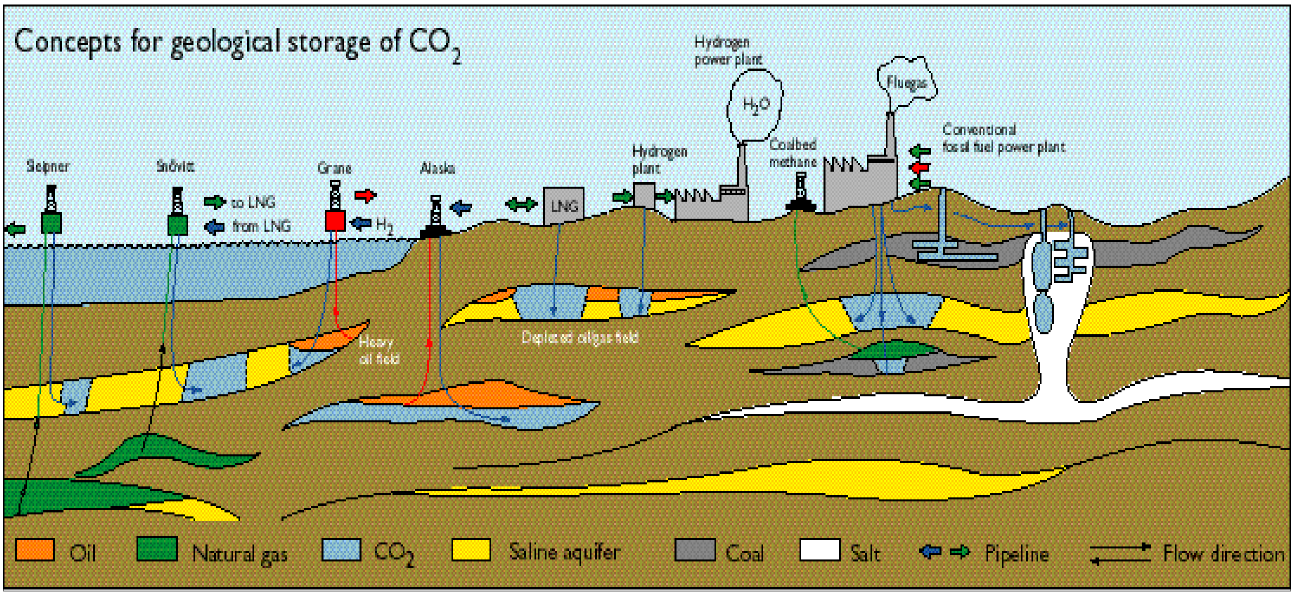

Illustration of some of the numerous geological settings favourable for subsurface storage of Carbon Dioxide.

THE GESTCO PROJECT

A joint research project conducted by 8 national geological surveys:

- **GEUS Geological Survey of Denmark and Greenland**
- **BGR Federal Institute of Geoscience and Natural Resources, Germany**
- **BGS British Geological Survey**
- **BRGM Geological Survey of France**
- **GSB Geological Survey of Belgium**
- **IGME Institute of Geology and Mineral Exploration, Greece**
- **NGU Geological Survey of Norway**
- **NITG-TNO Geological Survey of the Netherlands**
- **in cooperation with Ecofys Energy and Environment, The Netherlands**

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Reprint of paper presented by Niels Peter Christensen, GEUS at the 5th International Conference on Greenhouse Gas Control Technologies, August 13-15, 2000, Cairns Australia

INTRODUCTION

Power generation is the largest individual sector contribution approximately one third of the anthropogenic CO_2 emissions to the atmosphere. Nearly all power generation from fossil fuel takes place at major facilities, facilitating CO_2 capture and sequestration. Total EU (+Norway) emissions of CO_2 from thermal power generation were some 950 million tonnes in 1990, the Kyoto agreement reference level.

The Kyoto objective for the EU imply a reduction of 8% (relative to 1990) of the greenhouse gas emissions (Table I), corresponding to +/- 600 million tonnes per year of CO_2 between 2008 – 2012. An ongoing research project, the GESTCO project, will provide the first documentation that, for the emission sources within the selected key areas, sufficient geological storage capacity is available for at least 30 years and possibly much longer. Cost of energy will obviously increase, but it is anticipated that electricity production cost price will be comparable to that of renewables.

It would further have major implications for the European power generating industry which today is totally dominated by fossil fuel combustion with enormous emissions problems. The identification and siting of subsurface CO_2 storage capability can be expected to have considerable effect on the planning for and future siting of fossil fuel plants. In Norway there are plans to build several major, coastally sited, natural gas-fed electricity generating plants. It is obvious that their siting should be, in part, based on the availability of a suitable subsurface CO_2 storage facility.

Hydrogen power plants, using natural gas as a feed stock, are being considered as a viable future option in a number of countries with natural gas supply systems. In such plants separation of the natural gas into hydrogen and CO_2 will take place prior to combustion of the hydrogen. Emissions will be water vapour and the concept includes geological storage of the considerable volumes of clean, separated CO_2 in saline aquifers or in (heavy) oil fields, using the CO_2 to enhance oil recovery. Such power plants would also be able to supply hydrogen or methanol for automotive transport powered by fuels cells. The siting of such plants will again be dependent on the availability of subsurface CO_2 storage facilities.

As the search for oil and gas proceeds into geographically more remote areas the widespread transport of Liquified Natural Gas (LNG) will become commonplace. In order to produce LNG the gas first has to be cleansed of CO_2, and it is essential that the siting of such cleansing plants are seen in relation to suitable subsurface CO_2 storage facilities.

STATE OF THE ART

Several methods for CO_2 emission avoidance or storage have been devised. These methods include:

- **renewable energy (hydro, wind, solar, geothermal and biomass),**
- **chemical/biological removal (e.g. afforestation and greenhouses),**
- **fuel switching (replacing coal with oil, and oil with natural gas for lower CO_2 emissions per energy unit),**
- **ocean sequestration (dissolution of CO_2 in sea water at great depths)**
- **geological storage in deep sedimentary formations (see figure on cover).**

Storage of CO_2 in deep saline aquifers is technically feasible as demonstrated at the Sleipner gas field in the Norwegian North Sea. Since 1996, 1 million tonnes of CO_2 has annually been injected into saltwater saturated sands at depths below 800 m. The CO_2 at Sleipner occurs as a natural constituent in the hydrocarbon gas and is separated from the sales gas prior to pipeline export.

In a previous study *The underground disposal of carbon dioxide* a broad brush survey indicated that the theoretical underground storage space available for CO_2, primarily in the North Sea, might be sufficient for hundreds of years of emissions from power generation. Onshore and thus closer to the emission sources storage potential is also indicated to be large, but geographically variable. In addition, storage reservoir quality and the sealing of the reservoirs are also parameters of major importance that require quantification.

THE GESTCO RESEARCH PROJECT

The principal objective of GESTCO is to make a major contribution to the reduction in CO_2 emissions to the atmosphere and so ensuring Europe a continued stable supply of affordable and environmentally acceptable energy. The project will thus seek to provide an answer to the question: Is the geological storage of CO_2 a viable method capable of wide-scale application?

Via case studies from differing regions the project will aim at determining the true storage potential of subsurface for CO_2 in a number of regions within Europe (Fig. 2). The case studies will:

- **Produce detailed geological data for each area**
- **Evaluate the significance of all possibilities for alternative uses of the subsurface**
- **Evaluate the impact of any leak that may occur**
- **Define the location of potential storage areas relative to large point sources of CO_2.**
- **Conduct reservoir simulations of each potential storage area**
- **Make an economic evaluation of the storage potential in each area**
- **Economic comparison of carbon dioxide free electricity production cost from conventional and renewable energy sources**

The results of the project will encompass evaluation of the storage potential in the representative areas combined with inventories of power plant (and major industrial) point sources of CO_2 emission. Through a number of realistic scenarios, cost of CO_2 storage will be calculated; per tonne of CO_2 avoided and as increase in the cost of electricity production. A dedicated decision support system will be developed in the project and this facility will be made publicly available on the internet, enabling other users (e.g. power companies and policy makers) to evaluate their own 'emission source – storage site' scenarios.

REPRESENTATIVE STUDY AREAS

Four of the most promising types of geological storage are being studied. These storage types include:

1. Onshore/offshore saline aquifers with or without lateral seal.
2. Low enthalpy geothermal reservoirs.
3. Deep methane-bearing coal beds, and abandoned coal and salt mines.
4. Exhausted or near exhausted hydrocarbon structures.

The various storage types are know to exist in several regions throughout Europe. The study will investigate the storage potential of the four main storage types in selected areas (Fig. 2), using these as representative settings which, at a future time, could provide the backbone of an atlas of European geological storage capacity. The four different types of geological storage will be studied in some detail through the selection of eight representative study areas (Table II) – some of which represent a geographical collation of examples (Fig. 3).

Storing carbon dioxide close to emission sources will almost inevitably introduce the 'complications' associated with physical planning and public perception/acceptance of subsurface CO_2 storage. To that end, a public hearing will be held.

The main project participants are the geological surveys of Denmark, Great Britain, The Netherlands, France, Belgium, Norway, Germany and Greece, working jointly within the EuroGeoSurveys association. Also participating are the firms Ecofys (NL) and Vito Engineering (B), as well at the Greek National Power Corporation, the French Geothermal Company, and the National Oil Company of Denmark (DONG). A number of energy companies are currently negotiating entry into the project.

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Table I: CO_2 Emissions from Fuel Combustion in million tonnes of CO_2 (IEA 1998 Edition).

	1990	1996	96/90	Target*
Austria	59.4	62.7	5.6%	-13%
Belgium	109.1	124.6	14.2%	-7.5%
Denmark	52.9	72.3	36.6%	-21%
Finland	54.4	64.2	18.2%	0%
France	378.3	384.3	1.6%	0%
Germany	981.4	904.7	-7.8%	-21%
Greece	72.3	77.6	7.4%	+25%
Ireland	33.2	36.5	9.7%	+13%
Italy	408.2	420.0	2.9%	-6.5%
Luxembourg	10.9	9.1	-16.2%	-28%
Netherlands	161.2	186.4	15.6%	-6%
Norway	29.8	31.6	6.3%	+1%
Portugal	41.5	49.1	18.3%	+27%
Spain	215.0	235.6	9.6%	+15%
Sweden	52.7	59.4	12.7%	+4%
United Kingdom	585.3	582.8	-0.4%	-12.5%
EU	3215.7	3269.2	1.0%	-8.0%
USA	4873.4	5324.5	9.3%	-7%
Japan	1061.8	1177.7	10.9%	-6%
World Total	21252.1	22741.7	7.0%	-5.2%**

* Target applies to all six greenhouse gases
** Agreed reduction for developed countries

Table II: Matrix for definition of CO2 source/storage site scenarios

TYPE OF STORAGE	SOURCE OF CO_2	REPRESENTATIVE STUDY AREAS
Deep saline aquifers	Industrial sources of the densely populated areas around the Southern North Sea	A: Southern England, The Netherlands, Belgium, NW Germany, N France
	Power plants and major industrial point sources based on fossil fuels; high proportion of coal use.	B: N-DK-G sedimentary basins: conventional structural closures and very large sand bodies, possibly with chalk acting as chemical seal.
	LNG production and new generation power plants using natural gas or hydrogen as fuel	C: Offshore/near shore Northern and Central Norway
	Fossil fuel, mostly lignite, power plants and major industries.	D: Greek onshore sediments (power) and offshore sediments (refineries and cement factories)
Geothermal reservoirs	Metropolitan areas (power plants and industry): Greater Paris area, Copenhagen-Malmø metropolitan region	E: The Paris Basin (established geothermal area) and the Copenhagen – Southern Sweden area (EU Interreg II region with geothermal potential)
Coal Bed Methane *(CBM)*, Coal and Salt Mines *(CSM)*	Central Western European power plants and heavy industry from Channel Coast to Berlin	F: Belgium, The Netherlands, Germany, and Northern France.
Hydrocarbon structures	Power plants and major industrial sources throughout Europe.	G: Germany , The Netherlands; British, Danish and Norwegian North Sea; Aegean Sea

Figure 2: Preliminary map indicating geographical extend of the project.*(T.Wildenborg, NITG-*

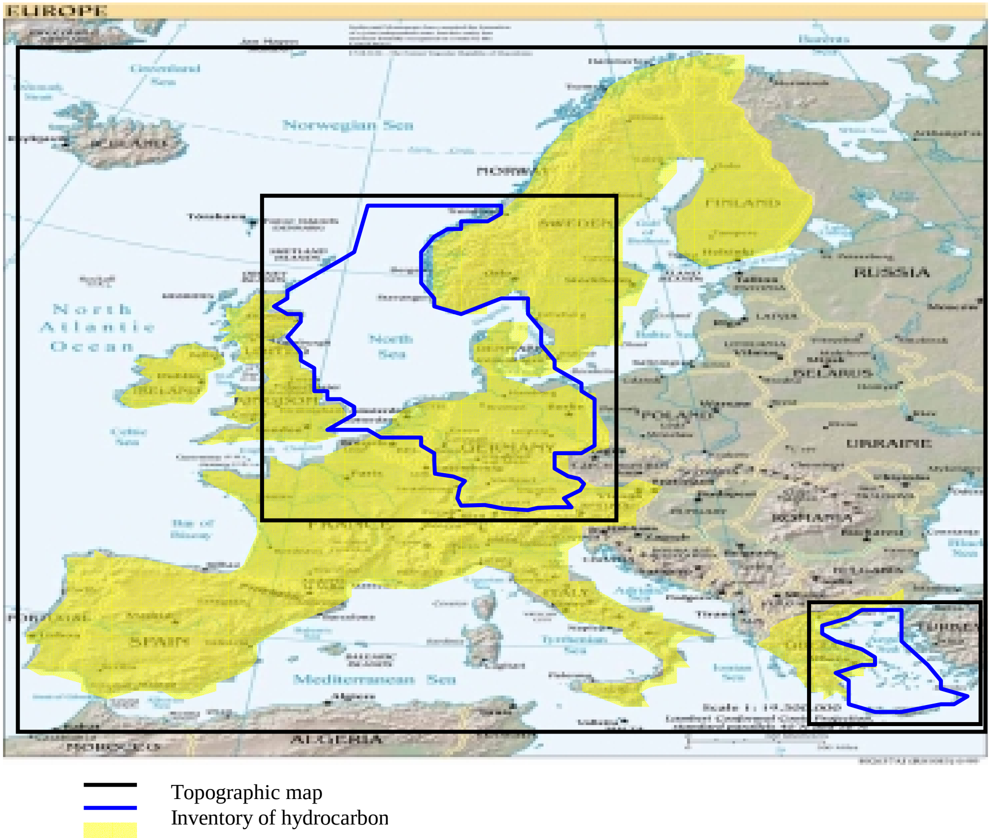

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Figure 3: German sedimentary basins with indications of 3 representative study areas (P. Gerling, BGS Hannover)