GEOLOGIJA *46/2*, 425–428, Ljubljana 2003

GESTCO GIS and DSS – A GIS solution to assist with decision making for the geological storage of CO_2 from fossil fuel combustion

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Key words: GESTCO GIS, DSS, CO_2, geological storage, GIS

Abstract

This project aims to determine whether the storage of CO_2 underground, such as is taking place at the Sleipner West Gas Field, North Sea, can become a practical industrial solution to major CO_2 emissions into the atmosphere from large point sources such as power plants. If this is a practical proposition it could make an impact on the enhanced greenhouse effect caused by man emitting CO_2 into the atmosphere.

As part of the project a dedicated Geographical Information System (GIS) and a Decision Support System (DSS) have been developed. The GIS enables the user to view and analyse the large amounts of data collected, whilst the DSS enables emission – source – storage scenarios to be planned and cost evaluated. A webGIS was also set up to enable the project partners to view the progress of data collection and to assist with data checking.

Introduction

Following the Kyoto climate conference in 1997 a consortium of 8 European national geologic surveys launched a project in 2000, spanning 3 years, which has studied the technical and economical feasibility of wide-scale application of CO_2 storage in the subsurface. This EU project was entitled "European Potential for Geological Storage of Carbon Dioxide from Fossil Fuel Combustion" (acronym GESTCO).

The EU Kyoto objective implies a reduction of 8% (relative to 1990) of the greenhouse gas emissions. This amounts to a reduction of approximately 600 million tonnes per year of CO_2 between 2008 and 2012. Power generation has the largest individual contribution of CO_2 emission and this amounted to 950 million tonnes in 1990. As nearly all fossil fuel power generation occurs at major facilities there is potential for CO2 capture and sequestration.

The GESTCO project has aimed to make a major contribution to the possibilities of reducing CO_2 emissions into the atmosphere by investigating whether geological storage of CO2, as is taking place at the Sleipner West Gas field, is a viable method capable of wide scale application. The GESTCO project

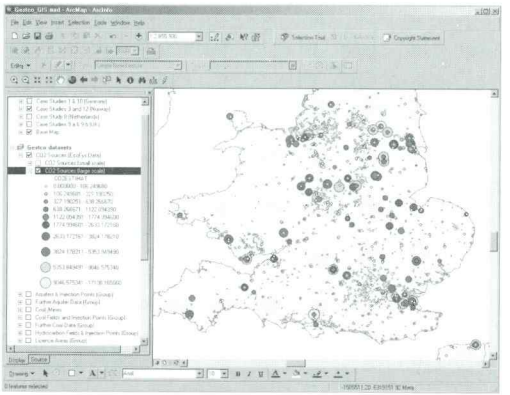

Figure 1. View of UK CO2 sources in the GIS

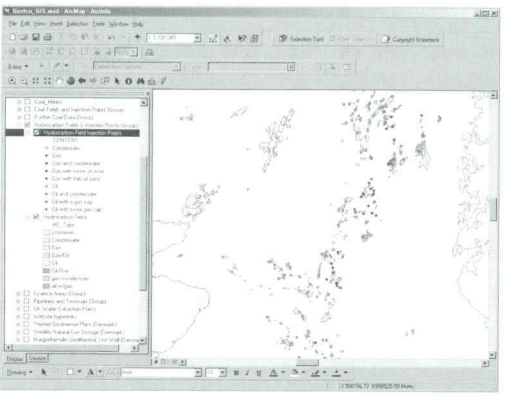

Figure 2. View of Hydrocarbon Field sinks in the North Sea

aims to provide documentation and data to show that for emission sources in key selected areas there is sufficient geological storage capacity.

A large amount of data has been collected from the participating countries (Belgium, Denmark, France, Germany, Greece, Netherlands, Norway and the UK) for use in the GIS and the DSS. An inventory of major CO_2 sources has been made and this data will be combined in the GIS with information on potential underground CO_2 sinks and potential CO_2 transport routes. Four main types of underground storage sites have been investigated, these being onshore/offshore saline aquifers, low enthalpy geothermal reservoirs, deep methane-bearing coal beds and abandoned coal and salt mines, and exhausted or near exhausted oil and gas fields. The participating countries have also researched several case studies. The DSS, developed through customisation of ESRI's ArcMap® using VBA, provides the tools for evaluation and comparison of the costs and economic risks of realistic combinations of CO_2 emission sources, transport possibilities and storage capacities for various scenarios input by the user, it takes into account all cost relevant parameters for sequestration, transport and storage of the CO_2.

GESTCO GIS

The objective for the GESTCO GIS was to produce a Geographical Information System that would incorporate the wide range of data provided by the project partners and allow the partners and end-users meaningful access to the data. The GIS allows users to simultaneously view one or more layers of data including the location of the CO_2 sources and possible CO_2 sinks, it will also enable the user to perform extensive on screen analysis on all the available data. Geoscience datasets included in the GIS comprise aquifer injection points and aquifer area location, hydrocarbon field injection points and hydrocarbon field locations, coal mines, coal field and coal field injection points as well as the locations of the CO_2 sources, existing pipelines and pipeline terminals. Many other datasets have also been provided to enhance the capabilities and information held within the GIS, for example geological, tectonic zone and ecosystem data.

CO_2 Sources

The CO_2 sources database was built by EcoFys from data provided by the project partners. The database incorporates a large amount of data including information on the location, emission and sector (power, chemical etc). The data is then converted into shapefile format for visualisation within the GIS as a point dataset with scale rendering to give users an immediate view of the size of emissions.

CO2 storage (sinks) datasets

These datasets, which include the aquifer injection points, hydrocarbon field injection points and coal field injection points were collated from data provided by each partner. The data incorporates information on the storage capacity for CO_2, depth, pressure

and porosity of the sink. The hydrocarbon field injection points database was built by TNO whilst the other datasets were provided as shapefiles by each partner and merged into single datasets by the British Geological Survey (BGS).

To provide access to additional information, held within the websites of the Geological Surveys involved, along with other websites, links to external websites have been set upwithin the GIS.

The GIS, which has been developed using ESRI's ArcGIS®8.2 software, uses ArcMap, whilst the datasets, which were initially provided in shapefile or Excel format, are stored within a personal geodatabase which uses Microsoft Access. The personal geodatabase enables the storage of all the datasets in a single location which makes transfer of the GIS data from one location to another much easier. This is a very important requirement for the GIS, as well as the DSS, as it is necessary to ensure the systems are easily transferable to the project partners and the end users on completion of the project. To assist in the ease of this transfer process the GIS has also been set up using relative pathnames which ensures that the GIS will always pick up the location of the datasets.

There has been some customisation of the GIS to allow users, who are unfamiliar with the GIS environment, to use the system more effectively. This customisation has taken place using ESRI ArcObjects within the VBA environment. The main customisation has been to develop a selection tool that will allow users to select from within the datasets based on the CO_2 emissions or CO_2 storage capacity. This tool also allows the user to save their selection as a new shapefile should they wish to keep it for further analysis.

Copyright information is also a feature of the GIS. Users must agree to abide by the copyright of the data before the GIS will open fully and there is also the ability to access the copyright information from within the GIS should users wish to read it again.

Case study data

Many case studies have been carried out for the project and the data from these has been included in the GIS. As this data has been provided in many different formats and is specific to particular case studies this data has not been merged into single datasets as with the general GIS datasets. There are many maps and diagrams that have been provided for the case studies, as it is highly useful to be able to view such maps, diagrams and seismic profiles, from within the GIS, hyperlinks have been set up. This enables the user to click on a feature with the hyperlink tool and view any maps or documentation associated to the feature.

GESTCO WebGIS

It was decided that the best way to allow the project partners and end-users to monitor the progress of the data collection was to set up a web-based GIS system. The GESTCO webGIS was developed using ESRI's ArcIMS® software, which allows the easy dissemination of GIS data over the internet. The webGIS does not have the full functionality of the GESTCO GIS, however it does allow users to view the datasets on screen and perform simple queries on the data. The webGIS also became a very useful resource towards the end of the project when it was used by the project partners to do the final checks on the data they had provided in the preceding 3 years.

GESTCO DSS

As part of the project The Netherlands Institute of Applied Geoscience TNO, one of the GESTCO participants has developed a decision support system. This DSS calculates costs and economic risks of realistic combinations of CO_2 emission sources, transport possibilities and storage capacities for each of the selected areas.The DSS is founded on ArcView®8.2 extended with Spatial Analyst. The end user interfaces with ArcView®8.2 and defines a removal scenario by selecting a CO_2 source and a storage location (sink).

After scenario composition, Spatial Analyst will determine the least costly transport route. For this ArcView®8.2 is fed with data which expresses costs related to pipeline construction; costs determined by aspects like land use, elevation, artificial and natural barriers, existing pipeline corridors are added in grid format so that Spatial Analyst can take these into account when searching for the optimal route.

Once the scenario is completed with an optimal routing between sources and sink, calculation models will kick in and evaluate remaining technical and economical aspects of the problem definition: the costs for CO_2 separation at the source is calculated, the size of the CO_2 flow in time from source(s) to sink is used to calculate the needed dimensions of pipelines and the number of compression stations along the route. Storage models will evaluate the chosen sink on volumetrics (pore volume, compressibility, sweep efficiency) and injectivity behavior (fluid mobility, injection rate, number of needed wells). These calculation models are implemented outside ArcView®8.2 and coupled as Dynamic Link Libraries.

When all calculations are finished, the results are gathered within ArcView®8.2 and the whole scenario evaluation will be presented to the end user in numbers and graphs. And, of course, the chosen route is geographically mapped. The end user will get an answer on whether it is technically possible to separate, transport and store an amount of CO_2 over time and how much such a scenario will cost.

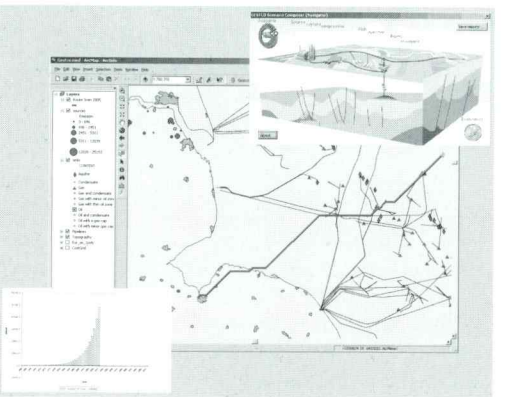

Figure 3. Gestco DSS

Conclusions

This project has enabled the development of two highly useful systems that should prove invaluable in the decision making process with regards to possible CO_2 sequestration.

The data collected is a valuable resource and the GIS provides the best interface for accessing and viewing the data. The DSS has been the vehicle that comprises many of the geoscientific and economical study results that were gathered during the GESTCO project. Although it should be viewed upon as a prototype, it is already being used in other projects. Several assumptions and simplifications were made for the sake of implementation. As with many DSS systems the results of a scenario run will not result in deadly accurate figures. The results should be applied as selection criterion for many different scenario runs. The DSS aims however to provide insight in the power of costs that are at hand when dealing with CO_2 sequestration.

It is the intention to continue to develop and maintain these systems within future projects relating to CO_2 sequestration.

Acknowledgments

The authors would like to acknowledge the project co-workers from GEUS (Geological Survey of Denmark), 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) and EcoFys Environment and Energy for the work done to provide the data included in the GIS and DSS.

This paper was produced with the kind permission of the Director of the British Geological Survey.