TOGEOS - Towards geological storage of CO_2 in the Czech Republic
Executive Summary

TOGEOS is a Czech-Norwegian research project supported by the EEA Grants and Norway Grants as well as by the Ministry of Education, Youth and Sports of the Czech Republic. Formally, it is a sub-project of the Research Support Fund managed by the National Training Fund.

The project started on January 1, 2009 and ended on September 30, 2010 (duration of 21 months). The Czech Geological Survey (CGS) was coordinating the project, with the International Research Institute of Stavanger (IRIS) as the project partner. The project budget was 222,223 EUR.

The main objective of the project was to significantly increase the level of knowledge and preliminary evaluate the most promising geological structures potentially suitable for storage of CO_2 in Czechia – i.e. the deep saline aquifers of the Central Bohemian Permian-Carboniferous basins and (semi-) depleted hydrocarbon fields of eastern Moravia. The project goals were achieved by fulfilling the following tasks related to the project's main objective, namely:

- performing a multicriterional analysis of three partial Permian-Carboniferous basins (Žatec, Central Bohemian /Roudnice/ and Mnichovo Hradiště) and selecting the most promising one for further evaluation;
- assessing the storage potential of the Česká Kamenice Basin (which has not been evaluated previously);
- increasing the knowledge of mineralogical, petrophysical, lithological and geochemical properties of both reservoir formation and seal rocks by laboratory analyses;
- updating the initial volumetric model of the selected basin into a real basin model by introducing newly measured data, sequence-stratigraphic and thermal history analyses, etc.;
- building an initial static geological model based on the existing data;
- building a preliminary reservoir model of the selected storage site and performing the simulations of potential CO_2 injection and storage;
- exploring possible implementation of CO_2 for enhancing oil recovery from the Czech (Moravian) oil reservoirs and their potential subsequent conversion to CO_2 storage sites;
- disseminating the results of the project by presentations at international scientific events, by publications in scientific journals and organising an open workshop at the end of the project.

Based on a multicriterional analysis of data available for the three partial Permian-Carboniferous basins (Žatec, Central Bohemian /Roudnice/ and Mnichovo Hradiště), the Central Bohemian /Roudnice/ basin was selected as the most suitable one for further research. Moreover, partial aquifers within this basin were analysed, and the deepest Mirošov Member aquifer was chosen as the most promising target for reservoir modelling and injection simulations.

The Česká Kamenice Basin was also evaluated from the CO_2 storage potential point of view. The results showed that this basin may be also a possible target of further research, providing quite interesting storage capacity, with some uncertainties needed to be addressed, such as the presence of a rather shallow sealing of the formation, lack of available deep geological data, etc..

In order to increase the level of geological knowledge on the basin and the rock properties of the Central Bohemian Basin and to provide sufficient data for 3D modelling and simulation purposes, a comprehensive review of all available data and information was performed, including archive reports, archive borehole records, databases, etc. From the archive records

of petrophysical properties 704 measured borehole samples were selected, analysed and used, in addition to archived data on results of hydrogeological (pumping) tests and well logs, for building of the geological basin models.

Some of the data were re-evaluated and re-interpreted, including 17 seismic reflection sections, and new correlations between the boreholes were derived. Well-logs from 21 boreholes were analysed (mainly resistivity and gamma-ray logs) and new parameters were calculated – porosity and clay content. Finally, new facial maps of the target horizons were also constructed.

Due to uncertainties on the quality and processes used to obtain core sample measurements, 45 core plugs were drilled from archive borehole cores stored at the core depository at Kamenná in order to perform new laboratory tests. In addition, a 60-m-deep shallow analogue borehole, Cvr-1, was drilled that penetrated the target geological formation at a shallower depth and provided further rock samples for laboratory testing and new well-log data. New porosity (52 samples) and permeability (21 samples) tests were performed in both Czech and Norwegian laboratories, as well as reflectance measurements (13 samples), detailed petrological characterization (41 samples), detailed mineralogy (6 samples) and organic geochemistry analyses incl. pyrolysis (21 samples). Both the archive and newly acquired data served as input for 3D basin and reservoir modelling.

Based on the data and information described above, a three-dimensional geological model of the Central Bohemian Basin was created and formed the geometric basis for both the basin-evolution and reservoir models. The basin-evolution model, created in the PetroMod^{TM} software, builds on the sequence-stratigraphic and thermal history analyses that reconstruct the history and evolution of the basin in geological past.

A preliminary static geological model based on the existing data was developed using the Petrel^{TM} software that embraces a distribution of crucial reservoir parameters within the structure, i.e. porosity, permeability and net-to-gross ratio (describing the sand vs. clay content). Following a careful evaluation of the modelled basin and identification of the most promising section of the basin that meets basic CO_2 storage criteria, this model was used to extract a formation sector that was subsequently used to perform preliminary dynamic simulations of CO_2 injection into the aquifer's storage formation.

The initial sensitivity analyses performed using a mechanistic model showed that while the storage capacity of the structure (based on porosity of the rocks and the net-to-gross ratio) may be sufficient, the critical factor is the injectivity of CO_2 that depends mainly on the formation rock permeability, reservoir connectivity, storage formation size, and injection well type, location and completion. At present stage, the available geological data do not allow a detailed formation characterization (reliable permeability and porosity data, sufficient and effective description of reservoir heterogeneity such as faults, fault conductivity, presence of low or high permeability zones, sealing effectiveness, etc.). Hence, the CO_2 injectivity, its migration into reservoir rock and containment issues currently remain uncertain and most probably could be quantified with more certainty only after additional, reliable data (seismic, core, testing, etc.) from the actual reservoir depth become available.

Full-scale simulations using the appropriate reservoir model have confirmed that, based on the given geological formation heterogeneities, absolute rock permeability and overall aquifer volume, including optimized position and completion of injection wells, were the most influencing parameters defining a potential success of the injection rates and amount of CO_2 stored. The results have also shown that it is possible to inject the required CO_2 target volume for a reservoir scenario that contains an optimistic absolute permeability field, sealing faults in the north and the presence of two water production wells, which could be viewed as an attempt to addressing (partially) pressure communication of the simulated aquifer region

to adjacent pore volumes in the geological basin. Finally, it is necessary to better characterize the formation to reduce the current level of uncertainties and better understand the available reservoir volumes where CO_2 can be stored as well as formation permeabilities and reservoir heterogeneities.

Last but not least, screening of Moravian oil reservoirs was also performed in order to explore the CO_2 storage potential of the fields and to explore possibilities of CO_2-driven enhanced oil recovery (CO_2-EOR) techniques to increase existing recovery factors. The potential use of CO_2 as an Enhanced Oil Recovery (EOR) agent (either miscible or immiscible CO_2-flooding) to increase oil recovery from five mature Czech oil reservoirs followed by CO_2-storage have been evaluated. Primary screening of the five fields' potential for EOR by CO_2-flooding has been carried out by comparing the reservoir description, oil composition/properties and reservoir conditions with proposed criteria in the literature. In the binary screening, the same parameters were compared with data from oil reservoirs where miscible CO_2-flooding has been carried out. The IRIS' SWORD software was then utilized to further evaluate the two most promising assets with the respect of existing EOR processes and make preliminary evaluations based on the existing data. Finally, the CO_2-storage potentials for the two most promising oil reservoirs were evaluated based on volumetric techniques due to the lack of appropriate data for a more thorough evaluation of their storage capacity.

In conclusion, the preliminary project results show that the properties of the selected aquifer structure – the Central Bohemian Basin – are on the limit of suitability for CO_2 storage. A final go/no-go decision cannot be taken without incorporation of new, reliable reservoir formation data, as described above, that will enable us to improve the current reservoir characterization and reduce inherent uncertainties of reservoir model predictions. Such new data can only be acquired by means of reservoir assessment methods like deep drilling, seismic reflection, well-logging, hydrogeological testing, core analyses, etc.

As far as the Czech oil reservoirs is concerned, the analysis of 5 representative structures shows that two such hydrocarbon-bearing structures may have a promising CO_2-EOR potential with the possibility of their subsequent conversion into CO_2 storing sites.