The objective of the MOVECBM project was to improve the current understanding of CO2 injected in coal and, hence, the migration of methane, thus ensuring a long-term, reliable and safe storage. In the MOVECBM project, modelling and laboratory work were performed that were based on parameters of the previously investigated test site in Kaniów, Poland by the EC RECOPOL project. However, the former CO2 injection well from the RECPOL project was now used to produce gas from the coal seams in order to improve the CO2 storage and CO2 'Enhanced Coal Bed Methane' (ECBM) understanding. The composition of this gas was continuously monitored to define the actual adsorption of CO2 that was injected in the period August 2004 till June 2005 in the coals seams during this RECOPOL project.

Besides the field production test in Kaniów, a small-scale combined injection and production experiment was carried out in the Velenje coal mine in Slovenia. Here, in the coal, horizontal injection and production wells were used to investigate adsorption, desorption and migration processes for local coal conditions. The results were expected to provide the missing information between the larger scale field experiment in Kaniów and the laboratory work.

The above mentioned experiments allow testing optimal storage and production regimes, but also the corresponding optimal monitoring methodology. Besides the coal reservoir and the cap rock, also the wells and the (near) surface were monitored. Monitoring and verification guidelines for site certification were derived from modelling results and compared to broadly accepted standards.

In summary, the objectives and activities of the MOVECBM project are:
- to prove that the CO2 is safely stored in the coal, understand the adsorption rate into the coal matrix, where it is physically bound to the coal;
- to improve the physical accessibility to methane for optimal production;
- to improve reservoir models using field data from this pilot, resulting in better tools to analyse CO2 storage and ECBM economics in the future;
- to determine optimal monitoring for characterising migration of CO2 and CH4 in coal;
- to determine optimal monitoring for possible leakage to the surface: sides of the reservoir, through the cap rock, along the wells, from surface to atmosphere;
- verification if the CO2 and CH4 migration is behaving as predicted from models within accepted boundaries.
The project was structured in five work packages (WP) as follows.

WP 1: Improving storage understanding and performance
The main objectives of the work package were:
- to gain better understanding of the adsorption kinetics and diffusivity of gases into the coal/matrix as this is a key parameter of ECBM that has received little attention to date;
- to develop accurate models able to predict the long term effect of CO2 injection (cap-rock and adsorption to coal);
- to investigate how to influence the accessibility to the coal fracture system (macro-scale, e.g. horizontal wells) and the coal matrix (micro-scale, e.g. improving pore accessibility).

The new reservoir simulations allowed to better understand the results of the ECBM field test in Poland and the mine experiment in Slovenia.
- The low water production observed in the back-production of the former injector in Poland could be explained by an effective CO2 sweep that carried away the water during the injection. Furthermore, the reduced permeability caused by coal swelling prevented the water to flow back towards the injector.
- The CO2 injection test in the Velenje coalmine could be adequately simulated with Shell's simulator MoReS and the permeability reduction was successfully modelled with the swelling model of Bustin.

However, the improved pressure communication between the wells, which was observed weeks later, could not be modelled. The modelling of this effect will require the coupling of a geo-mechanical simulator and reservoir simulator, because the creation of fractures depends on the stress fields. In task 1.5 this gap in the current models is addressed.

WP 2: Monitoring of gas migration in coal reservoirs and assessment on caprock integrity
The aim of work package 2 was to monitor the migration of the injected CO2 in coal and to monitor released CH4 from the coal. The monitoring was performed to verify if the CO2 behaves as predicted within accepted boundaries. Therefore also the cap rock over the coal seams was monitored. A system was devised, including time-lapse profiling, and varying monitoring techniques. These techniques differ in applied locations and sampling, but together should result in an optimal, dynamic image of the subsurface. The WP also included the site preparations.

WP 3: Wellbore integrity
The objective of this work package was to better understand the well material degradation mechanisms and how to monitor them by sensor systems, for proper risk analysis and identification of remedial actions. For that purpose, laboratory characterisation, in situ measurements and modelling studies were conducted in parallel.

The important mechanisms or features that could potentially lead to upward migration or leakage are:
- defects at the interfaces between casing and cement, or between the formation and the cement;
- long-term deterioration of cement plugs and sheath by wet CO2 under in-situ conditions (post-abandonment), which could lead to changes in cement properties (i.e. permeability).

The above two mechanisms would increase the casing exposure to CO2 and corrosion will be accelerated.

Based on this analysis, the activities in WP 3 Wellbore integrity pursued three complementary directions:
- assessment of the completion integrity and its monitoring versus time;
- modelling of the completion deterioration versus time and the evaluation of leakage rates;
- characterisation of completion materials (cement and casing) under down-hole conditions.

The impact of the work performed in WP 3 has been high. First, the experiments on the type of corrosion experienced in CO2 injection wells have allowed to confirm that uniform corrosion and blistering are the main phenomena (with little or no pitting observed) and that a siderite layer offers some protection. The experiments also allowed identifying EIS and LPR as two promising methods for corrosion monitoring in-situ. Furthermore, the time-lapse logs showed the value of high-resolution imaging of steel and cement to characterise CO2 effects. In particular, they confirmed that only negligible corrosion phenomena happened to the steel, that there is some evidence of a (tiny) CO2 leak between cement and steel (that carbonated the cement over 1 km), and that coal - because of creep or swelling - compresses cement on the casing guaranteeing a good seal in the absence of a strong injection pressure. This is the first time that a leak path during injection has been identified and quantified.

Finally, simulations allowed for the quantification of possible long-term leaks and to characterise risk. Given the cement quality and low CO2 pressure, the risk was confirmed negligible, and the abandonment and monitoring practices recommended by local regulations
were deemed sufficient.

WP 4: Environmental monitoring and risk assessment and safety (HSE)
A critical component of long-term geological sequestration of anthropogenic CO2 will be the ability to adequately monitor a chosen site to ensure public and environmental safety. Near-surface monitoring is particularly important, as it is possible to conduct sensitive and direct measurements at the boundary between the subsurface and the biosphere (i.e. surface water or atmosphere). While discontinuous surface monitoring is often performed, continuous monitoring is preferable if one hopes to observe a leak in its early stages to allow for rapid remedial action. Also, natural trends (i.e. natural background values and their variation) can better be determined. Based on this assumption, the core of these WP activities was focused on the development of low cost and innovative tools for the continuous monitoring of CO2 concentration and flux.

This was done to:
- control post-injection conditions (baseline);
- detect and measure any seepage to the biosphere, identifying potentially hazardous leakages of CO2;
- observe CO2 migration in (and around) the storage reservoir;
- test and calibrate site performance simulations;
- perform analysis, modelling and interpretation for a generic protocol for future storage projects.

Based on the results of risk assessment, undertaken safety precautions as well as based on the real case of ‘Kaniow Operational site’ the existing mining and geological law regulations shall be verified and following amendments are proposed: changes in the being currently in force directives shall go in the same direction. It is proposed to classify greenhouse gas intended to be stored underground, in the frame of EU regulation - not as a waste.

WP 5: Results and verification
The activities that are undertaken here aimed at cooperation with partners from China on the subject of ECBM. The main goal of this cooperation was the establishment of a long-term relationship between European and Chinese partners in order to prepare a pilot ECBM site in China in the near future. For this reason, a selection of potential areas was undertaken within the project. These could then be compared to prospective locations in Poland.

In conclusion, China has huge resources of coal that are not attractive for mining in the next decades, and probably longer. These coal seams can be targeted for CBM production. Many of these coal basins show low production rates and low recovery factors. Current developments in drilling technology should be followed and applied to improve these performance parameters. However, injection of CO2 may provide a further enhancement of the production (therefore ECBM production). Because the CO2 is adsorbed on the coal it is stored in the reservoir and, if obtained from an anthropogenic source, thereby reduces the CO2 emissions to the atmosphere. Subsurface coal in China is likely to hold the largest theoretical storage capacity for CO2 compared to other underground storage options. ECBM projects can work in China if the economic, infrastructural, and geological constraints are taken into account in the planning.

The planned CBM production in the selected areas (Hancheng and Jinshi) in the next years makes them attractive. More detailed study should be undertaken to check these criteria and to make a development plan to test the application of ECBM in these areas. The selected sites in Poland currently lack planned CBM production in the next years, which makes them less attractive for ECBM before 2012.

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