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SCIENCE FOR A SUSTAINABLE DEVELOPMENT

Policy Support System for Carbon Capture and Storage

«PSS-CCS»

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FINAL REPORT PHASE 1
SUMMARY

Policy Support System for Carbon Capture and Storage

«PSS-CCS»

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The central goal of the project Policy Support System for Carbon Capture and Storage (PSS-CCS) is to build a tool capable of projecting the implementation of Carbon Capture and Storage in a Belgian context. Together with the simulator, a series of databases are needed on the three main elements in the CCS-chains: capture, transport and storage.

CO_2 concentrations in the atmosphere are on the rise due to human activities, and it seems advisable to control these levels in view of adverse climate effects. One of the possible techniques is Carbon Capture and Storage, which forms the main topic of this publication.
Capture refers to the separation of CO_2 into a concentrated stream. This can be done at large industrial sources, and in general three capture techniques are discriminated. In the post-combustion system, CO_2 is separated from the flue gases, produced by the combustion of the primary fuel in air. In the pre-combustion process, the primary fuel reacts with steam and air or oxygen in a first reactor to produce a mixture of mainly carbon monoxide and hydrogen. The carbon monoxide reacts then with steam in a second reactor to produce additional hydrogen, together with CO_2. This mixture is then separated. In the oxy-fuel combustion system, primary fuel is combusted with oxygen instead of air to produce a flue gas that is mainly composed of water vapour and CO_2.
After CO_2 capture, CO_2 is compressed for transport, commonly through pipelines. The CO_2 pressure should not drop below 7.5 MPa during the complete (pipeline) trajectory in order to avoid two-phase flow and to transport it at a sufficiently high density.
For geological storage, three types of formations are suitable: depleted oil and gas reservoirs, deep saline aquifers, and coal seams and (coal) mines. For the storage of CO_2 in a liquid or supercritical phase, CO_2 is commonly stored in formations below 800 m depth. Based on the lower CO_2 density compared to water, a sealed cap rock is required on top of the CO_2 storage reservoir. Additional trapping results from capillary forces, dissolution in formation water and mineral precipitation. In coal sequences, adsorption is an essential trapping mechanism.

The current large CO_2 emitters in Belgium are potential targets for CCS projects and already give a first indication of the relevance of this technique for Belgium. The technical overview is given on the main capture technologies that can be used in the power sector. At the end of this chapter, these techniques are compared regarding their performance and cost.
The current industry is an important starting point. The overview comprises Ammonia, Cement, Ethylene, Ethylene oxide, Glass, Hydrogen, Iron and Steel, Lime, Power, Refineries and other sectors. Current CO_2 production is dominated by sources that emit over 500 Mton/y, which is in general favourable for CCS projects. Pure CO_2 streams represent only a few percentages of the total emissions.
Capture technologies are relatively well described for the power sector. A comparison of the main technology types reveals clear differences regarding fuel price, capacity, charge factors, etc. Nevertheless, the relevant economic parameter, which is the cost of electricity, is very comparable for al technologies. It is therefore not possible to identify which technology will dominate. In fact, it is likely that most of them will find their application.
Different geological storage options for Belgium exist. For the Flemish region the focus is on the aquifer storage options, while for the Walloon region coal gets most attention. For the international context, the storage options, capacities and costs in our neighbouring countries are assessed.
In Flanders, four aquifer complexes are considered. The Upper Cretaceous to Palaeocene carbonates occur at sufficient depth in the north of the Campine basin and in the Roer Valley Graben and have good injectivity and porosity. Seals are present in the overlying Cenozoic, but the target area is small.
The Lower Triassic sandstones of the Bundsandstein Formation have good porosity and are in the Roer Valley Graben overlain by sealing formations. Although the injectivity may be lower, it is regarded as a promising target for CO2 storage.

The Upper Carboniferous sandstones, the Neeroeteren Formation, have good porosity and permeability, but sealing is incomplete or uncertain.
The Lower Carboniferous carbonates, known as the Dinantian carbonates, are used for the storage of natural gas. Sealing is guaranteed, but the capacity of individual structures is relatively small.
In the Walloon region, the coal deposits from Hainaut to Namur, and some sites near Huy and Liège, were selected as most promising for the storage of CO_2. When assessing the storage potential, the whole coal sequence (coal, silt, sandstone) was taken into account. This new approach leads to a multiplication of the potential storage capacity.
The Dinantian aquifer is the best known aquifer target for CO_2 storage. It is especially its deepest and most horizontal part that is considered. This partly extends into France, and is considered as promising for CO_2 storage.
Belgium is a relatively small country. It also lacks gas or oil fields, which when depleted are often considered as first targets for CO_2 storage. Therefore also the storage potential in neighbouring countries is considered, more precisely for The Netherlands, Germany, France and the North Sea region. These show that exporting CO_2 would cost between 4 and 6 €/ton, except for the North Sea region where this would be 8 to 11€/ton.

Transport of CO_2 by pipeline is an important link in the chain of CCS. The technical requirements of pipelines and CO_2 purity are important parameters. Also, an estimation procedure for determining suited pipeline diameters is proposed, and the different cost aspects of pipeline construction and operation are addressed.
An enhanced formula for the calculation of pipeline diameters is proposed which allows to specifically include effects of height differences, local losses and frictional loss, and uses the Manning coefficients in order to avoid iterative calculation.

Possible safety issues exist concerning leakage of CO_2 from the geological reservoir to the surface. These risks are very low, but nonetheless need to be investigated. I most cases, a detailed case-study is needed to fully understand a reservoir's architecture and its possible leakage risks. A summary of a case study dealing about the Verloren Kamp structure is included in the report.

The Markal-Times model is software that enables a user to represent a complex energy system as system of linear equations, and has been used to build a model for the electricity sector in Belgium. This is used as reference scenario, and is extended with data on capture technologies and in a more rudimentary way also transport and storage. The simulations show that CCS can contribute significantly to decarbonisation of the electricity sector, up to 50%, when the CO_2 prices is higher than 25 €/ton.

PSS is capable of making stochastic projections, and it details routing costs and storage aspects. This potential was demonstrated.
PSS is a bottom-up simulator designed to provide ad-hoc projections for the implementation of CCS. In view of this particular scope, it is capable of making detailed cost estimates for transport of CO_2 using least-cost pipeline routing and makes use of uncertainty predictions on the availability of CO_2 sinks. In general, it pays specific attention to uncertainty at scenario level.
Two scenarios, based on the main Markal scenario, are used to demonstrate its application and flexibility. These largely confirm the Markal results, but also highlight the hazards of technology lock-in and importance of open access to transport and storage infrastructure. The effects of these are significant, and may largely undo the anticipated environmental benefits of CCS.