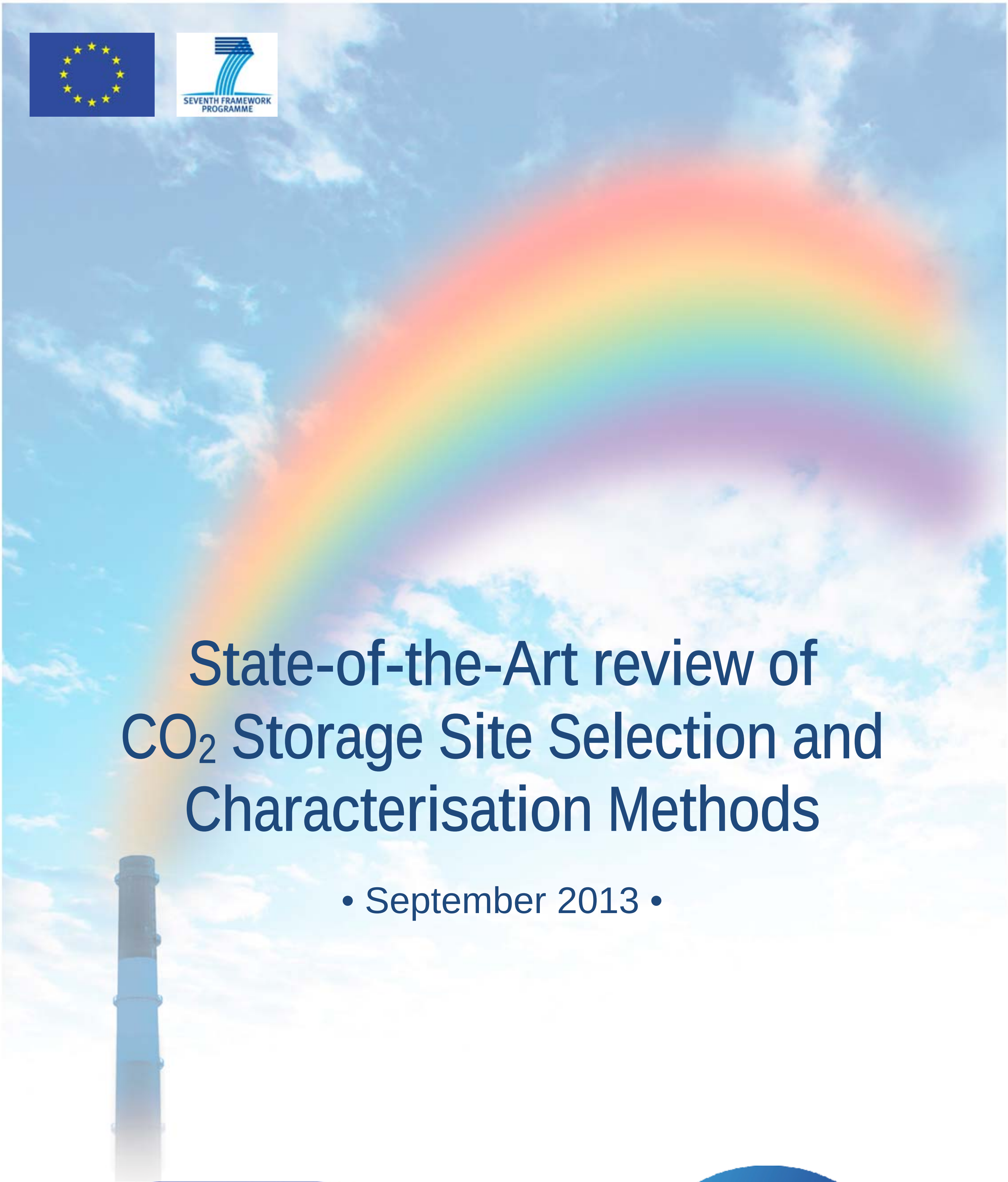

State-of-the-Art review of CO_2 Storage Site Selection and Characterisation Methods

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CGS Europe
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Action on CO_2 Geological Storage

CO_2GeoNet
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CGS Europe Key Report

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EXECUTIVE SUMMARY

Carbon dioxide Capture and Storage (CCS) is a technology that could contribute significantly to reduced CO_2 emissions to the atmosphere. By capturing carbon dioxide emitted from industrial processes, compressing it and injecting the CO_2 into underground geological reservoirs of porous rock for permanent storage, it provides a bridging solution to mitigate the climate change while renewable energy sources and other low carbon industrial technologies are developed to large-scale implementation.

The selection and characterisation of potential CO_2 storage sites are essential steps in progressing a CCS project. The site selection process should demonstrate that the site has sufficient capacity to store the expected CO_2 volume and sufficient injectivity for the expected rate of CO_2 capture and supply. The integrity of the site has to be assessed for the period of time required by the regulatory authority, so as avoid any unacceptable risks to the environment, human health or other uses of the subsurface.

The main objective of this report is to identify and review site selection and characterisation methods. This report presents and discusses all the steps required to assess the capacity, performance and integrity of a site. Simulation of CO_2 storage in an underground formation requires a complex multi-disciplinary effort, with the analysis of a number of interacting processes, including geology, multi-phase flow and transport, geochemistry and geomechanics. A site characterisation first calls for the geological characterisation and modelling of the site at basin and reservoir scales and the modelling of flow and transport mechanisms so as to simulate the short-term to mid-term behaviour of the storage. As well as hydrodynamic effects, geomechanical effects generated by the injection of a large volume of fluid in the subsurface have to be modelled over a long period. Modelling geochemical and biological processes is essential to understand the geochemical feedback on the reservoir properties and the trapping mechanisms that will occur. All these skills and knowledge are required to assess potential environmental impacts and risks. The estimation of the economical viability of the project is also essential to decide whether a geologically suitable storage site can actually be developed for CCS. In parallel with the technical aspect of characterising the site, public perception and acceptance appears to be a potential major impediment to deployment of CCS and so social activities towards local communities have to be performed at a very early stage.

Geological characterisation of the site (Chapter 2)

The first step in site selection is the screening of suitable formations and structures against specific suitability criteria and a more or less parallel assessment of storage capacity. In the case of saline aquifers, there is a sequence of capacity estimates that form a conceptual “storage capacity pyramid” ranging from initial assessments of geology to feasibility studies. Hydrocarbon fields, and to a lesser extent coal beds, have a narrower range of capacity categories and uncertainties because of the pre-existing knowledge available. Site selection should include a comprehensive assessment of quality and integrity of caprock as well as feasibility of the reservoir. Then site ranking follows, based on results of all previous studies; the problem is to weight the criteria against storage safety and feasibility.

Flow modelling (Chapter 3)

Computer simulation of CO_2 storage reservoir dynamics is one of the technologies that have been developed in the oil and gas industry. Flow modelling evaluates the behaviour of injected CO_2 based on the active processes in the reservoir. Flow modelling can be used in different phases of a CO_2 storage project. Before starting injection, the plume migration pathway and storage capacity of the reservoir are estimated using simulation models. During operations, models may show whether the project is performing as planned. Post-operational use of flow modelling helps the quantification of secondary trapping mechanisms and prediction of the plume behaviour. The predictive model is calibrated and refined by comparing field data and model results for the estimation of longer-term performance. The reservoir modelling study requires site-specific parameters in order to simulate the dynamic behaviour of the injected CO_2. Several mechanisms control the spread and storage of CO_2 in the storage medium, such as buoyancy forces, diffusion, dissolution into the formation fluid and the phase behaviour of CO_2. Therefore, simulation models are required to handle fluid interactions, mobility and density differences, salinity dependant dissolution and capillary effects. Besides CO_2 storage in the deep saline aquifers or depleted gas or oil reservoir, coal seams having CO_2 adsorption capacity can also be used as a storage medium. There are several numerical models that have different features and capabilities including TOUGH2, TOUGHREACT, Eclipse, CMG, PumaFlow, *etc.* These models are tested and being used to simulate several field projects. Depending on the conditions of the field and the project requirements, flow models have been generated and a better understanding of the processes associated with long-term geological CO_2 storage has been achieved.

Reactive flow modelling (Chapter 4)

Reactive flow modelling is a promising tool for assessing long term effects, predicting the spatial and temporal evolution of injected CO_2 and related gas-fluid-rock interactions, and assessing well integrity. Reactive flow modelling offers a wide set of useful tools for assessing the geologic storage site in different operational phases: pre-injection, during injection and post-injection. The modelling required, and the resolution that can be achieved during the site selection phase depends mainly on the availability of data and the geology of the storage site.

Coupled Geomechanical and Flow Modelling (Chapter 5)

Injection of CO_2 into a geological formation results in hydrodynamic effects as wells as pore pressure changes, which in turn affects the stress state. During the injection phase of a CO_2 storage project, the increase in pressure changes the effective stress and may lead to rock deformation, which may result in shear slip or tensile opening of pre-existing faults, or creation of new fractures. Therefore, modelling the geomechanical properties of the reservoir along with the fluid transport is vital for the safe storage of CO_2. The reservoir pressure starts to decrease when CO_2 injection ceases. The reservoir is considered to be secure against geomechanical failure as the pressure decays towards a stable condition. Compression of both the injected and in-situ fluids and expansion of the pore space may lead to ground lift and, in some cases, seismicity. The reservoir properties (*e.g.* permeability) may also be affected. The development of a static 3D geologic model, the careful assessment of the stress field and coupled modelling of pore pressure and stress changes, help the assessment of possible fault/fracture development and surface heave. The data required for coupled geomechanical and flow modelling include rock compressibility, Young's modulus, Poisson's ratio, compressive strength, and formation fracture pressure. The coupled geomechanical and flow simulations should be used to assess the likelihood of potential leakage and rates relative to key risks, such as CO_2 entry into the caprock.

Environmental Impact and risk assessment (Chapter 6)

Risks from the geological storage of CO_2 primarily result from the consequences of unintended leakage from the storage formation. Such risks might range between short and potential longer-term, that can be larger or smaller, diffuse leakages. Depending on the CO_2 storage site setting, onshore and offshore effects may arise. Risk assessment is the process that examines and evaluates the potential for adverse health, safety and environmental effects on human health, the environment, and potentially other receptors resulting from CO_2 exposure and leakage of injected or displaced fluids via wells, faults, fractures, and due to seismic events. The identification of potential leakage pathways is integrated with a Measurement, Monitoring and Verification (MMV) plan. The risk assessment results are used to ensure the safety and acceptability of geological storage. The process involves determining both the consequences and likelihood of an event. Risk mitigation is the planning for and implementation of contingency plans, should the need to remediate adverse impacts arise. A good monitoring and mitigation plan reduces the risk associated with many potential consequences.

Economic analysis (Chapter 7)

Costs estimates on CO_2 storage involve a high degree of uncertainty, given the significant variations in technical characteristics, scale and applications between projects. There is also uncertainty over how costs will develop with time. Site selection and the economics of storage will drive the commercial feasibility of large-scale integrated CCS projects and without appropriate storage options CCS may not become a cost-effective CO_2 mitigation option.

The Zero Emissions Platform has recently published a study on CO_2 Storage costs, 'The Costs of CO_2 Storage, Post-demonstration CCS in the EU'. The cost estimates reported range between €1-7/tonne CO_2 stored for the cheapest option (onshore depleted oil and gas fields with re-usable wells) to €6-20/tonne CO_2 stored for the most expensive alternative (offshore deep saline aquifers). Uncertainty ranges within each case are in line with the natural variability of storage candidates. Key drivers influencing the economics of storage were found to be the reservoir capacity (higher costs for smaller reservoirs); the site location (higher costs offshore than onshore); the amount of existing site information (more available information for depleted oil and gas fields allow for lower costs, little information for deep saline aquifers require higher costs); the existence of re-usable infrastructure (wells, offshore structure); and the reservoir quality.

Public perception and acceptance (Chapter 8)

Based on past experiences, non-technical aspects of the selection of CO_2 storage sites such as public perception and acceptance have become as important as technical aspects. A number of social research studies have been carried out over the years to investigate public perception of the technology. An important outcome of these studies is that social features are unique to each site, requiring a case by case approach. Communication strategies need to take into account the varied cultural patterns of the communities involved. In this report, open access sources of information are used to compile a reference list of relevant studies.

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