CO_2 Storage

Carbon dioxide capture and storage (CCS) in deep geological formations is one of the most promising emerging technologies for large-scale reduction in CO_2 emissions. The technology for CO_2 storage has been in use in several places since 1970s. Experience with CO_2 storage projects world wide proves that CO_2 can be stored safely without leakages. At present there are no technical barriers that hinder full scale implementation of geological storage of CO_2. What is needed to realize this technology is the establishment of an internationally agreed regulatory framework that can govern its deployment.

Semere Solomon, 21/02-2007 (updated by Aage Stangeland 09/10-2007)

CCS is a good and viable option for reducing CO2-emissions because it can be implemented on a large scale [1]. If CCS is fully implemented there is a potential of capturing and storing 236 billion tons of CO_2 globally by 2050 [2]. This corresponds to a 33 % reduction in global CO_2 emissions in 2050 compared to today's emission levels. In order to have a significant effect on atmospheric concentrations of CO_2, storage reservoirs would have to be large relative to annual emissions.

Possible storage sites

Geological storage of CO_2 can be undertaken in a variety of geological settings in sedimentary basins. Sedimentary basins are depressions or areas of subsidence with infillings of sediments either offshore or onshore. Within these basins, oil fields, depleted gas fields, deep coal seams and saline formations are all possible storage formations (Figure 1). Other geological formations which may serve as storage sites include caverns, basalt and organic-rich shales. In general, geological storage sites should have: (1) adequate capacity and injectivity, (2) a satisfactory sealing caprock that is a rock (e.g. clay stone or shale) that prevents from escaping the gas to the surface and (3) a sufficiently stable geological environment.

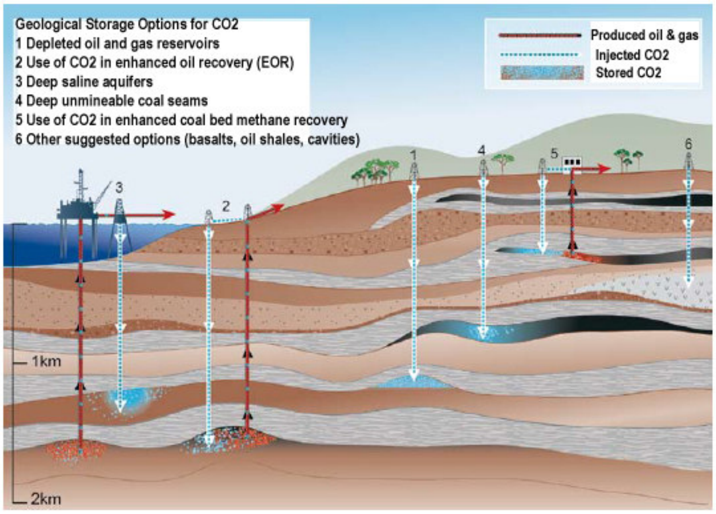

Figure 1: Options for storing CO_2 in deep underground geological formation [1].

Adequate porosity and thickness (for storage capacity) and permeability (for injectivity) are critical. The storage formation should be capped by extensive confining units (such as shale, salt or anhydrite beds) to ensure that CO_2 does not escape into overlying, shallower rock units and ultimately to the surface. Extensively faulted and fractured sedimentary basins or parts thereof, particularly in seismically active areas, require careful characterization to be good candidates for CO_2 storage.

Geological storage of CO_2 requires compression of CO_2 to allow injection. This is done by compressing the CO_2 to a dense fluid state known as 'supercritical'. This supercritical state is achieved by exposing the CO_2 to temperatures higher than 31.1° C and pressure greater than 73.9 bars. The density of CO_2 will increase with depth, until about 800 metres or greater, where the injected CO_2 will be in a dense supercritical state. Estimates of global storage capacity indicate that 675 – 900 Giga tonnes CO_2 ($GtCO_2$) can be stored in oil and gas fields, 3 - 200 Gt CO_2 in unminable coal seams and 1000 – 10000 $GtCO_2$ in deep saline formations [1]. This means that the storage capacity for CO_2 in geological formations is much higher than the global annual CO_2 emissions, which were 26 $GtCO_2$ annually in 2004 [3].

Ongoing activities/projects

CO_2 injection and/or storage in geological formations has been practiced since early 1970s. Information and experience gained from these projects, which include a large number of existing enhanced oil recovery projects, acid gas projects, industrial analogues and underground natural gas storage projects, provide additional indications that CO_2 can be safely injected and stored at well-characterized and properly managed sites for very long periods of time (hundreds to thousands of years) (Figure 2). The offshore gas field Sleipner, in the middle of the North Sea (Figure 2), has been injecting 1 million ton CO_2 per year since 1996. This is a commercial scale project, which involves several different actors, is a good example of CO_2 storage in deep saline aquifers [4].

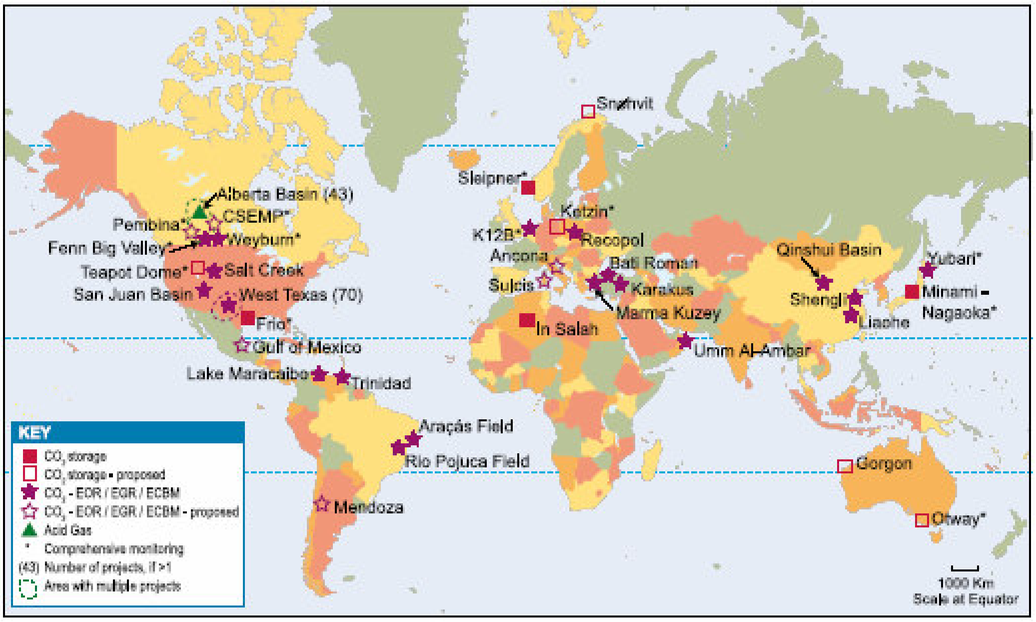

Figure 2: Location of sites where activities relevant to CO_2 storage are planned or under way [1].

Storage mechanisms

At depths below about 800–1000 m, CO_2 has a liquid-like density that provides the potential for underground storage in the pore spaces of sedimentary rocks. CO_2 can be trapped underground by various storage mechanisms, such as:

(1) Trapping below an impermeable, confining layer or caprock (Structural and stratigraphic trapping)
(2) The CO_2 is retained or adhered on the surfaces of the pore spaces of the storage formation so that it becomes contained as immobile phase (Residual CO_2 trapping)
(3) Dissolved in the fluids contained in the pore spaces of the formation (Solubility trapping), and
(4) Additionally, it may be trapped by reacting with the minerals in the storage formation and caprock to produce carbonate minerals (Mineral trapping).

CO_2 becomes less mobile over time as a result of multiple trapping mechanisms, further lowering the prospect of leakage, which builds the confidence in geological security of carbon dioxide storage (Figure 3).

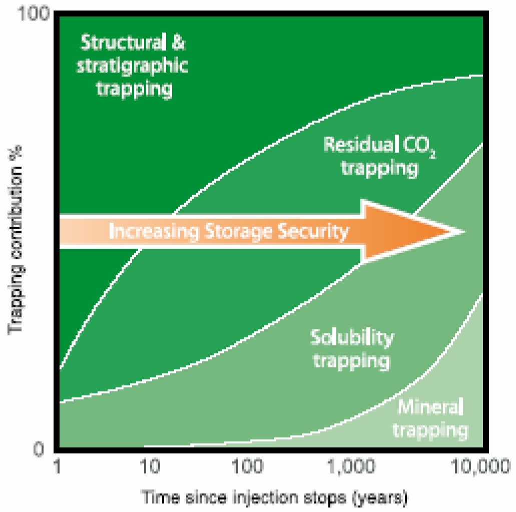

Figure 3: Storage security depends on a combination of physical and geochemical trapping. Over time, the physical process of residual CO_2 trapping and geochemical processes of solubility trapping and mineral trapping increase [1].

Site characterization and monitoring

Site characterization is a prerequisite to safe geological storage of CO_2. Site characterization means evaluation of the storage site in terms of its potential storage suitability, capacity and security for injecting CO_2. Documentation of the characteristics of any particular storage site will rely on data that have been obtained directly from the reservoir. The following data sets are essential in any storage site characterization:

- Geological site description from wellbores and outcrops are needed to characterize the storage formation and seal properties
- Seismic surveys are needed to define the geological structure found below the ground surface and identify faults or fractures that could create leakage pathways
- Formation pressure measurements are needed to map the rate and direction of groundwater flow, and
- Water quality samples are needed to demonstrate how the deep and shallow groundwater zones or areas are separated

Performance prediction of a site can be made using models that are available to predict what happens when CO_2 is injected underground (Figure 4). Monitoring is needed to demonstrate that CO_2 remains contained in the intended storage formation(s). This is currently the principal method for assuring that the CO_2 remains stored and that performance predictions can be verified. Monitoring the behaviour of the CO_2 requires a base line survey that should be carried out before injection starts (e.g. 1996 in Figure 4). This survey will provide the point of comparison for subsequent surveys (e.g. 1999 and 2001 in Figure 4). This enables to track the fate of the injected CO_2 and to verify available reservoir and geological models.

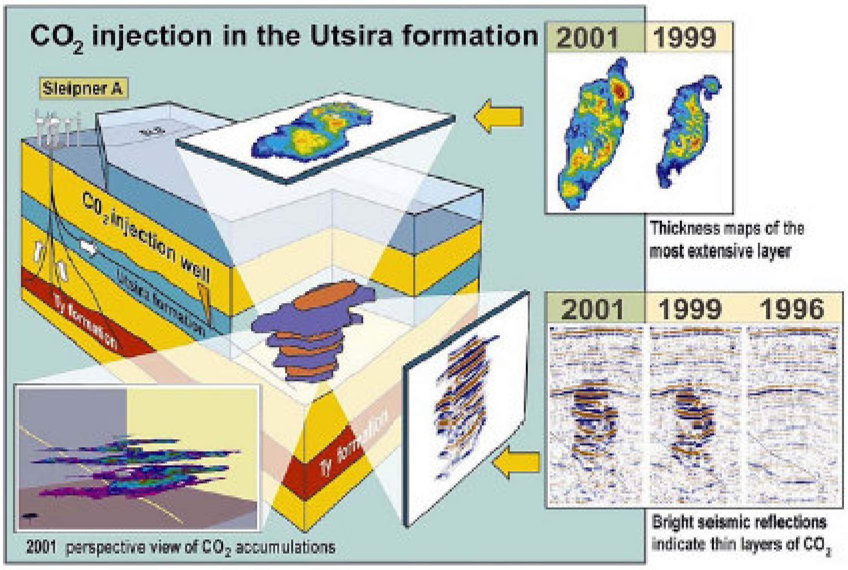

Figure 4: Repeat seismic surveys and position of injected CO_2 [5].

Status for CO_2 storage

CCS is getting attention as a viable option to mitigate climate change. The success of CCS as a greenhouse gas mitigation strategy depends on the regulatory framework established to govern its deployment. Efforts are underway in the development of national and international rules and regulations for CCS projects [6] [7]. A consistent effort to address the major unresolved regulatory issues related to CCS, such as long-term stewardship of the stored CO_2, clarification of whether CO_2 is defined as industrial or hazardous waste, access and property rights, intellectual property rights, liability issues, and monitoring and verification requirements, is needed for rapid implementation of the technology. Additional information can be obtained from reference [8].

References:

[1] IPCC, 2005: IPCC Special Report on Carbon Dioxide Capture and Storage. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [Metz, B., O. Davidson, H. C. de Coninck, M. Loos, and L. A. Meyer (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 442 pp.

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[3] IEA 2006. World Energy Outlook. http://www.worldenergyoutlook.org/2006.asp

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[8] Solomon, S., Kristiansen, B., Stangeland, A., Torp, A.T. and Kårstad, O. 2007. A Proposal of Regulatory Framework for Carbon Dioxide Storage in Geological Formations, http://www.irgc.org/irgc/IMG/pdf/IRGC_CCS_BellonaStatoil07.pdf

Further reading

Best Practice manual, 2004: S. Holloway, A. Chadwick, E. Lindeberg, I. Czernichowski-Lauriol and R. Arts (eds.), Saline Aquifer CO_2 Storage Project (SACS), 53 pp.