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Carbon Capture and Storage (CCS): Overview, Developments, and Challenges

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Carbon dioxide capture and storage (CCS) is a technology that will allow the continued combustion of fossil fuels (coal, oil, gas) for e.g. power generation, transportation and industrial processes for the next decades. It therefore facilitates to bridge to a more renewable energy dominated world, enhances the stability and security of energy systems and at the same time reduces global carbon emissions as manifested by many western countries.
Geological media suitable for CO2 storage are mainly saline aquifers due to the large storage volumes associated with them, but also depleted oil and gas reservoirs or deep unminable coal beds. Lately, CO2 storage into mafic- to ultramafic rocks, associated with subsequent mineral carbonation are within the R&D scope and first demonstration projects are being executed. For all these storage options various physical and chemical trapping mechanisms must reveal the necessary capacity and injectivity, and must confine the CO2 both, vertically (through an effective seal) or horizontally (through a confining geological structure). Confinement is the prime prerequisite to prevent leakage to other strata, shallow potable groundwater, soils and/or atmosphere.
Underground storage of gases (e.g. CO2, H2S, CH4) in these media has been demonstrated on a commercial scale by enhanced oil recovery operations, natural gas storage and acid gas disposal. Some of the risks associated with CO2 capture and geological storage are comparable with any of these industrial activities for which extensive safety and regulatory frameworks are in place. Specific risks associated with CO2 storage relate to the operational (injection) phase and to the post-operational phase. In both phases the risks of most concern are those posed by the potential for acute or chronic CO2 leakage from the storage site.
Currently there are only few operations worldwide where CO2 is injected and stored in the subsurface. Some are related to oil production enhancement but the largest piece of cake is referring to R&D projects on a small-scale demonstration basis. Numerous further demonstration or small-scale commercial projects have been announced for the near future. Such developments demonstrate that there are no major technological barriers to widespread geological CO2 storage. Main challenges are rather on the public acceptance, legislation and commercial site. Commercially CCS costs are mainly dominated by the high costs of CO2 capture where, depending on the capture method, CO2 needs to be separated from the emission gas stream produced during energy production. Policy, legislation and regulatory framework issues are further hurdles that need to be considered for large scale implementation of this technology. Finally public acceptance of this technology will likely affect the large-scale implementation of CO2 geological storage.