CO_2 Capture and Storage

HIGHLIGHTS

■ **PROCESS AND TECHNOLOGY STATUS –** Carbon capture and storage (CCS) is a process that significantly reduces carbon dioxide (CO_2) emissions from fossil fuel combustion in power generation and in the industrial sector. CCS includes 3-steps, i.e. **CO_2 capture** by *decarbonisation* of fossil fuels or separation from flue gases and other gaseous mixtures; **CO_2 transportation** to the storage site - usually via pipelines; and **CO_2 storage** by injection of high-pressure supercritical CO_2 into geological formations, e.g. deep saline reservoirs, depleted oil and gas fields, and *unmineable* coal seams. In fossil fuel combustion processes, the CO_2 can be captured in pre-combustion mode (i.e. fossil fuel decarbonisation), in post-combustion mode (i.e. chemical separation from the flue gas), and by the oxy-fuel combustion (i.e. fuel combustion in oxygen-rich atmosphere). Apart from combustion, CO_2 can also be separated from gaseous mixtures, e.g. in natural gas fields with high CO_2 content or in chemical processes. The CCS process is based on well-known technologies, but has never been applied to large-scale power or industrial plants. The five large-scale, industrial demonstration projects that are currently in operation use CO_2 sources other than power plants (e.g. CO_2 from natural gas production or coal gasification). With a total storage capacity above 5 $MtCO_2$/y, these projects focus on CO_2 geological storage rather than on CO_2 capture. CO_2 underground injection and storage is also used in enhanced oil recovery (EOR) projects (mostly in North America) where the additional production of oil offsets the cost of CO_2 separation, transportation and injection. CCS applications in power generation are currently being demonstrated in relatively small (5-40 MW) pilot plants. A number of full-scale projects are currently underway or planned.

■ **PERFORMANCE AND COSTS –** CCS can reduce CO_2 emissions by more than 85% in power generation, and significant reductions are expected in other industrial sectors. In general, CO_2 separation from natural gas wells is a relatively easy and cheap process, but CO_2 capture from combustion processes is rather expensive and energy-consuming. CCS applications in power generation may involve reductions of the power plant efficiency between 8 and 12 percentage points, (typically, from 45% to 35% in coal power plants and from 60% to 50% in gas-turbine combined cycles). Today's costs of CCS in power generation is estimated between US \$50 to \$90/tCO_2 and may be even higher, depending on technologies and storage site location. This cost typically includes \$30-50/tCO_2 for capture, \$5-20/tCO_2 for on/offshore pipeline transport (100-200 km) and \$5-10/tCO_2 for injection, storage and monitoring in deep geological formations. Using CCS in power plants can increase the electricity generation cost to between \$20 and \$40/MWh. Assuming reasonable technology advances, the CCS cost is projected to fall to some \$30-35/tCO_2 by 2030, with a lower impact on the cost of electricity. While the cost of CCS in industrial applications (e.g. cement, iron and steel production) is significantly higher, the cost of CO_2 separation from natural gas fields with re-injection and storage in near geological formations is relatively low, ranging between \$5/tCO_2 (onshore) and 15/tCO_2 (offshore).

■ **POTENTIAL AND BARRIERS –** Assuming appropriate emission reduction policies and considering marginal costs of CO_2 abatement of up to \$180/tCO_2, the International Energy Agency projects that the CCS technology could make a contribution of up to 19% to the global greenhouse gas (GHG) emission reduction targets by 2050. This includes applications in power generation and industry. Prudent estimates suggest that the global geological storage potential amounts to at least to 2000 $GtCO_2$. At either the current (i.e. 28-29 $GtCO_2$/yr) or increased levels of CO_2 emissions, this would allow the storage of the global emissions for almost a century. However, the global storage potential in deep saline formations and in other sites could be well beyond this level (above 10,000 Gt). Today's main barriers to CCS deployment include: a) the need to demonstrate that geological storage is definitely safe and permanent; b) the need for international regulatory frameworks; c) possible social acceptance issues; d) the high investment and operation costs, and related increase in the electricity generation cost; e) the lack of specific policies (incentives) for emission reduction via CCS.

PROCESSES – Carbon capture and storage (CCS) technology could enable large (up to 90-95%) reductions of the CO_2 emissions in power generation and significant reductions in both fossil fuel transformations and energy-intensive industrial processes, e.g. cement, iron and steel production. These processes are prime candidates for CCS applications as they are large, concentrated sources of CO_2 and all together account for more than 65% of the global CO_2 emissions from energy use. The capture of CO_2 from dispersed and/or mobile sources such as the residential and transport technologies is more expensive and technically difficult. The CCS process is based on technologies that are widely used in the chemical and oil industry, but have never been integrated and applied in large-scale power and industrial plants. The process consists of three phases: **CO_2 capture** (via different processes in power generation and in industrial facilities); **CO_2 transportation** (usually via pipelines); and **CO_2 storage** in geological formations, i.e. deep (> 800 m) saline formations, depleted oil and gas reservoirs (possibly, with enhanced oil/gas recovery, EOR/EGR), unmineable coal seams, and sites with enhanced coal bed methane (ECBM) recovery. A number of CCS technologies and variants are being considered. All processes involve additional costs and efficiency reductions of the basic plant, and require further R&D.

Please send comments to Giorgio.Simbolotti@enea.it, Author, and to
Giorgio.Simbolotti@enea.it and Giancarlo Tosato (gct@etsap.org), Project Coordinators