Carbon capture and storage (CCS) is a process that significantly reduces carbon dioxide (CO₂) emissions from fossil fuel combustion in power generation and in the industrial sector. CCS includes 3-steps, i.e. CO₂ capture by decarbonisation of fossil fuels or separation from flue gases and other gaseous mixtures; CO₂ transportation to the storage site - usually via pipelines; and CO₂ storage by injection of high-pressure supercritical CO₂ into geological formations, e.g. deep saline reservoirs, depleted oil and gas fields, and unmineable coal seams. In fossil fuel combustion processes, the CO₂ 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, CO₂ can also be separated from gaseous mixtures, e.g. in natural gas fields with high CO₂ 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 CO₂ sources other than power plants (e.g. CO₂ from natural gas production or coal gasification). With a total storage capacity above 5 MtCO₂/y, these projects focus on CO₂ geological storage rather than on CO₂ capture. CO₂ underground injection and storage is also used in enhanced oil recovery (EOR) projects (mostly in North America) where the additional electricity production cost to between $20 and $40/MWh. Assuming reasonable technology advances, the CCS cost is projected to fall to some $30-35/tCO₂ 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 CO₂ separation from natural gas fields with re-injection and storage in near geological formations is relatively low, ranging between $5/tCO₂ (onshore) and 15/tCO₂ (offshore).

CO₂ Capture and Storage

**HIGHLIGHTS**

- **PROCESS AND TECHNOLOGY STATUS** – Carbon capture and storage (CCS) is a process that significantly reduces CO₂ emissions from fossil fuel combustion in power generation and in the industrial sector. CCS includes 3-steps, i.e. CO₂ capture by decarbonisation of fossil fuels or separation from flue gases and other gaseous mixtures; CO₂ transportation to the storage site - usually via pipelines; and CO₂ storage by injection of high-pressure supercritical CO₂ into geological formations, e.g. deep saline reservoirs, depleted oil and gas fields, and unmineable coal seams. In fossil fuel combustion processes, the CO₂ 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, CO₂ can also be separated from gaseous mixtures, e.g. in natural gas fields with high CO₂ 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 CO₂ sources other than power plants (e.g. CO₂ from natural gas production or coal gasification). With a total storage capacity above 5 MtCO₂/y, these projects focus on CO₂ geological storage rather than on CO₂ capture. CO₂ underground injection and storage is also used in enhanced oil recovery (EOR) projects (mostly in North America) where the additional electricity production cost to between $20 and $40/MWh. Assuming reasonable technology advances, the CCS cost is projected to fall to some $30-35/tCO₂ 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 CO₂ separation from natural gas fields with re-injection and storage in near geological formations is relatively low, ranging between $5/tCO₂ (onshore) and 15/tCO₂ (offshore).

- **PERFORMANCE AND COSTS** – CCS can reduce CO₂ emissions by more than 85% in power generation, and significant reductions are expected in other industrial sectors. In general, CO₂ separation from natural gas wells is a relatively easy and cheap process, but CO₂ 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/tCO₂ and may be even higher, depending on technologies and storage site location. This cost typically includes $30-50/tCO₂ for capture, $5-20/tCO₂ for on/offshore pipeline transport (100-200 km) and $5-10/tCO₂ 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/tCO₂ 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 CO₂ separation from natural gas fields with re-injection and storage in near geological formations is relatively low, ranging between $5/tCO₂ (onshore) and 15/tCO₂ (offshore).

- **POTENTIAL AND BARRIERS** – Assuming appropriate emission reduction policies and considering marginal costs of CO₂ abatement of up to $180/tCO₂, 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 GtCO₂. At either the current (i.e. 28-29 GtCO₂/yr) or increased levels of CO₂ 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 CO₂ 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 CO₂ and all together account for more than 65% of the global CO₂ emissions from energy use. The capture of CO₂ 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: CO₂ capture (via different processes in power generation and in industrial facilities); CO₂ transportation (usually via pipelines); and CO₂ storage in geological formations, i.e. deep (> 800 m) 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.

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