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Review

Comparative assessment of CO_2 capture technologies for carbon-intensive industrial processes

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ABSTRACT

This article presents a consistent techno-economic assessment and comparison of CO_2 capture technologies for key industrial sectors (iron and steel, cement, petroleum refineries and petrochemicals). The assessment is based on an extensive literature review, covering studies from both industries and academia. Key parameters, e.g., capacity factor (91–97%), energy prices (natural gas: 8 €$_{2007}$/GJ, coal: 2.5 €$_{2007}$/GJ, grid electricity: 55 €/MWh), interest rate (10%), economic plant lifetime (20 years), CO_2 compression pressure (110 bar), and grid electricity CO_2 intensity (400 g/kWh), were standardized to enable a fair comparison of technologies. The analysis focuses on the changes in energy, CO_2 emissions and material flows, due to the deployment of CO_2 capture technologies. CO_2 capture technologies are categorized into short-mid term (ST/MT) and long term (LT) technologies. The findings of this study identified a large number of technologies under development, but it is too soon to identify which technologies would become dominant in the future. Moreover, a good integration of industrial plants and power plants is essential for cost-effective CO_2 capture because CO_2 capture may increase the industrial onsite electricity production significantly.

For the iron and steel sector, 40–65 €/tCO_2 avoided may be achieved in the ST/MT, depending on the ironmaking process and the CO_2 capture technique. Advanced LT CO_2 capture technologies for the blast furnace based process may not offer significant advantages over conventional ones (30–55 €/tCO_2 avoided). Rather than the performance of CO_2 capture technique itself, low-cost CO_2 emissions reduction comes from good integration of CO_2 capture to the ironmaking process. Advanced smelting reduction with integrated CO_2 capture may enable lower steel production cost and lower CO_2 emissions than the blast furnace based process, i.e., negative CO_2 mitigation cost. For the cement sector, post-combustion capture appears to be the only commercial technology in the ST/MT and the costs are above 65 €/tCO_2 avoided. In the LT, a number of technologies may enable 25–55 €/tCO_2 avoided. The findings also indicate that, in some cases, partial CO_2 capture may have comparative advantages. For the refining and petrochemical sectors, oxyfuel capture was found to be more economical than others at 50–60 €/tCO_2 avoided in ST/MT and about 30 €/tCO_2 avoided in the LT. However, oxyfuel retrofit of furnaces and heaters may be more complicated than that of boilers.

Crude estimates of technical potentials for global CO_2 emissions reduction for 2030 were made for the industrial processes investigated with the ST/MT technologies. They amount up to about 4 Gt/yr: 1 Gt/yr for the iron and steel sector, about 2 Gt/yr for the cement sector, and 1 Gt/yr for petroleum refineries. The actual deployment level would be much lower due to various constraints, about 0.8 Gt/yr, in a stringent emissions reduction scenario.

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