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Up-to-date CO_2 capture in thermal power plants

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Abstract

An up-to-date review of CO_2 capture technologies for coal-fired power plants is presented. This study is based on EDF experience on CO_2 capture build through collaborative projects and pilot plants operation follow up. This review focuses mostly on most mature technologies and provides insight on the interest of least developed technology with high potential. Technologies are compared and assessed based on energy performance, maturity and economic criteria. A specific method for assessing uncertainties in this process is proposed.

Amine based post-combustion technology remains the best reference for short and medium terms with a tight competition with cryogenic oxy-combustion. Both share the highest maturity and similar energy performance in their most advanced embodiments. At the moment IGGC based capture looks less promising for power generation due to the high cost of the plant even without CO_2 capture. Regarding more innovative technology, promising candidates, such as inertial extraction, chemical looping combustion or oxy-fired CO_2 cycle, are highlighted but their effective development up to industrial ground is not guaranteed due to the constant improvement of reference technology and their difficulty to be retrofitted.

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Keywords: post-combustion, oxy-combustion, pre-combustion, chemical looping combustion, technico-economic analysis, cost uncertainties propagation.

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1. Context and objective

Power generation represents 40% of global greenhouse gas emissions related to energy (transport, heating and industries) and 78% of emissions from fixed sources. Coal-fired power plants emit more than 75% of CO_2 emissions of the power generation sector, i.e. they emit 30% of the anthropogenic CO_2. The generated electricity supplies residential houses as well as the tertiary sector or industries. Rapid economic growth of countries such as China and India has led to a substantial global CO_2 emissions raise, China having become now the world largest CO_2 emitter. While future coal power plants will go into service in China and India and existing power plants will continue to be operated in US, Australia and Europe, reducing global CO_2 emissions in the next decades remains an important challenge.. In this context, CO_2 capture and geological storage is an interesting technology that could help mitigate the impact of fossil fuel continuous use on global climate change.

The aim of this paper is to provide a state-of-the-art analysis of CO_2 capture technologies for coal-fired power plants. This report updates the previous synthesis [1] and has been performed within the framework of the EDF R&D project “Toward zero emission power plants”. This review focuses mostly on most mature technologies and provides insight on the interest of least developed technology with high potential.

2. Evaluation method

The three main technological pathways: post-combustion using chemical absorption, oxy-combustion with cryogenic air separation and pre-combustion with physical absorption, are studied regarding several evaluation criteria. The most mature processes are particularly assessed, innovative capture processes studied within the project are also evaluated in terms of foreseen performances. The objective is also to provide a synthesis of possible future development for these technologies.

2.1. Criteria definition

The following evaluation criteria have been retained to evaluate and compare the capture processes, including quantitative (mostly technical indicators) and qualitative criteria:

- Technology Maturity Level (TRL),
- Net efficiency loss, i.e. the difference between the power-plant net efficiency with and without CCS,
- Levelized cost of avoided CO_2 ($LCACO_2$),
- Operability, flexibility and risk levels (qualitative),
- Market (retrofit and/or new built),
- Technology interest,
- Technological gap,
- Environmental issues.

2.2. Maturity and efficiency loss evaluation

Technological maturity and energy performance evaluations are based on technological watch, EDF participation in collaborative projects and the utilization of pilot plants results reported in literature and pilot plants operated by EDF, e.g. Alstom AAP pilot plant in EDF’s Le Havre power plant or Skid ANSU (ANti-SUblimation or frosting-defrosting of CO_2, in EDF’s Vitry power plant). Investigated technological options include post-combustion capture processes using amine and ammonia absorption [e.g. 2-10], activated carbon adsorption [e.g. 11-13], solid CO_2 deposition [e.g. 14-16]; oxycombustion with cryogenic air-separation [e.g. 17-21], chemical looping combustion [e.g. 22-25]; and pre-combustion with physical absorption [e.g. 26, 27].