ABSTRACT
CO₂ capture from fossil fuel power plants is increasingly proposed for greenhouse gases emission mitigation. It can be applied to coal power stations (with boiler and steam cycle or with gasification) or to natural gas combined cycles (NGCC). The first case is probably the most important in a mid-term perspective, due to: (i) the larger amount of avoided carbon per unit of electricity produced, (ii) the larger strategic reserves of coal vs. natural gas. However, capture from NGCCs is more likely to be applied in the short-mid term, for many reasons (lower initial costs, lower technical risks, better operability, etc.) particularly relevant for near-term projects, e.g. large scale demonstration plants. Besides, a considerable fleet of modern and efficient combined cycles is now in service in many countries (e.g. Italy) and, potentially, it can be modified to capture operation.

This paper presents a detailed and comprehensive analysis of three near-term plant configurations for CO₂ capture: (i) amine post-combustion separation, (ii) syngas decarbonization, (iii) oxy-combustion. We address them as ‘near-term’ because they do not involve the development of components requiring unproven technology, i.e. novel components can be manufactured and operated by using available knowledge. The three configurations have been often addressed in the literature: however, in this paper we will consider the most efficient and updated technologies, comparing their performance on the basis of a common reference plant (FB technology gas turbine) and of a consistent set of assumptions. With more detail:

• The post-combustion option makes use of a conventional mono-ethanol-amine gas separation process. The operational parameters of the process (solution flow rate, purity of lean solution, stripping pressure) were optimized to achieve the best compromise between carbon removal efficiency and cycle efficiency. Exhaust gas recirculation techniques were not considered, to avoid modifications to the gas turbine and to make the configuration viable for modification of existing plants.

• The pre-combustion option has been intensively optimized, by the introduction of: (i) an air-blown reformer, (ii) a pre-reforming section, heated by the high temperature reformed syngas, (iii) a double shift reactor, to optimized the heat recovery and CO₂ conversion, (iv) an optimized separation process, combining the physical and chemical absorption properties of MDEA to minimize the energy requirements for the solvent regeneration.

• The oxy-combustion option includes: (i) a double column air separation unit with pumped oxygen, (ii) a semi-closed gas turbine cycle with a CO₂-H₂O expander feed by oxy-combustion products diluted by recirculated CO₂: for this particular gas turbine, the pressure ratio has been optimized to the higher values required by the different operating fluid; the turbine blade cooling aspects were considered in detail, (iii) a CO₂ compression process including the separation of inert gases (N₂, O₂, Ar).
The performance prediction shows that the best efficiency is achieved by post-combustion (51%, starting from a NGCC with 57.4%), followed by pre-combustion (49.7), both showing about 90% carbon capture. Oxy-combustion shows a lower efficiency (46%) with lower emissions (98% capture, virtually no CO, UHC and NO\textsubscript{X} emissions).

An indicative cost analysis was also performed. Again, the best solution is post-combustion with a cost of the avoided CO\textsubscript{2} of about 50 €/ton. On another point of view, by attributing some ‘damage factors’ to the various emissions (including CO\textsubscript{2} at 19 €/ton), the cost of electricity produced, inclusive of such ‘externalities’, rises from 65 €/MWh for the no-capture solution to 73-82 €/MWh of the various considered plants, a ‘sustainable’ increase for low carbon emission electricity.

\textit{Keywords}: NGCC, CO\textsubscript{2}, Capture, Oxyfuel, Amine, Shift.

\textit{Proposed Topic}: