A comparison of post-combustion capture technologies for the NGCC

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Abstract

The present work summarizes research from the BIGCCS research centre, where different technologies for post-combustion CO₂ capture has been evaluated with an integrated assessment approach: Results from process unit modelling with detailed knowledge about solvents or sorbents have been integrated with a Natural Gas Combined Cycle (NGCC) model. The model is defined by EBTF [1] with thermal efficiency: 58.1%, thus providing, as far as possible, consistent results for different capture technologies. 90% CO₂ capture rate was investigated as default. The NGCC plant without CO₂ capture has a net power output of 416.4 MW and emits 41.1 kg CO₂/s (~1 Mt CO₂/year at 7500 operating hours/year).

CO₂ capture with amines

A comparison was made between CO₂ capture with MEA and a Novel Generic Solvent (NGS) [2]. It was shown how replacing MEA with the NGS, introducing Exhaust Gas Recirculation and decreasing the reboiler pinch point from 20 to 10°C all lead to incremental improvements of the NGCC efficiency. Increasing the reboiler pressure from 1.85 bar to 3.5 bar did not increase the NGCC efficiency, since the reduced power requirement for the CO₂ compressor is balanced by increased steam pressure for regeneration (Figure 1). The process integration when capturing CO₂ with amines is straightforward and known: The absorber is placed after a flue gas cooler, downstream of the HRSG, and steam for solvent regeneration is extracted from the crossover between the IP and LP turbine. In the calculations in [2], it was assumed that the LP steam turbine efficiency was identical without and with CO₂ capture. In a process that will operate both without and with CO₂ capture, however, the LP steam turbine must be designed for large variations in steam flow, which may have a negative impact on the overall process efficiency [3].
Figure 1. NGCC efficiency with solvent capture

**CO₂ capture with high-temperature solid sorbent capture**

Two studies were made of the integration of Ca-looping into the NGCC with CO₂ capture[4], [5]. Results from these papers, as well as a novel process with integrated oxygen membrane can are assembled in Figure 2.

Figure 2. NGCC efficiency with Ca-looping capture.

The basic process with most mature technology has a very low efficiency (45.6%). Several improvements can however be made to the process, where solid-solid recuperator, hot recycle of CO₂ for fluidisation and the use of a future synthetic sorbent have the most significant impact on increasing the process efficiency. Capture process integration into the NGCC is more complicated than for solvent capture, since the Ca-looping absorber must be located between the gas turbine and the HRSG. This will, among other things, have an impact on the NGCC ability to respond rapidly to load changes, as well as the retrofitability of the capture technology. In brief, the Ca-looping
technology may not be practical for CO\textsubscript{2} capture from the NGCC, at least not in energy systems with a high requirement on rapid load response from NGCC plants.

\textit{CO\textsubscript{2} capture with polymeric membranes}

An investigation was made with the Attainable Region Methodology\cite{6} for a set of membrane properties reflecting a polymeric membrane of commercially available performance. The first results show, as expected, that NGCC efficiency is far below acceptable at 90\% CO\textsubscript{2} capture rate – around 35\% for the NGCC without EGR and around 45\% with EGR. However, reducing the capture rate to 60\% yields an efficiency penalty of around 4\%-points for the NGCC without EGR. Although the cost of the membrane systems are well above what is typically provided in the literature for amines, the results are a first indication of that optimised membrane systems at reduced capture rates are capture rates in the range of This indicates that reduced capture rates merit further attention for membranes, in particular when envisaging novel membrane systems with better permeance and/or selectivity.

Targets for membrane properties that make CO\textsubscript{2} capture cost- and energy efficient for capture rates will therefore be set in the paper with the Attainable Region Methodology. Therewith an indication will be obtained as to whether membranes, with their easy end-of-pipe installation, under some conditions may be an alternative to solvent capture from the NGCC. It must then be recognized that solvent development is ongoing and performance improvements will come in this area.

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