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Bridging the Thermal Gap: Exploring Heat Sources for Solvent-based CO_2 capture in Cement Plants

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Abstract

Cement production is a significant contributor to global CO_2 emissions, accounting for 7-9 % of anthropogenic emissions. As the cement industry works towards achieving carbon neutrality by 2050, carbon capture technologies are essential for mitigating emissions, particularly those produced during limestone calcination—a process inherent to cement manufacturing. Among the technologies available, solvent-based post-combustion CO_2 capture has emerged as the most mature and commercially viable option for the cement sector. This method employs chemical solvents, such as amines, to absorb CO_2 from flue gases, followed by thermal regeneration of the solvent to release the CO_2 for subsequent storage.

However, deploying this technology presents a significant challenge due to the substantial heat requirement for solvent regeneration. Cement plants often lack sufficient waste heat to meet this demand for solvent regeneration. Around 50-60 % of the total heat input to a cement plant is used directly in the clinker process. A large share of the remaining heat is used to dry the raw material fed to the cement plant. The main factor affecting the amount of heat available for solvent regeneration is, thus, the raw material moisture content. The plant configuration, such as the number of preheater stages and plant operating regime, contribute to the heat available to a lesser extent.

Earlier work (Roussanaly et al. 2017) has shown that how we supply steam greatly impacts the cost of CO_2 avoided in a cement plant, as steam costs account for nearly half the CO_2 avoided cost. In addition to heat recovery of excess heat in the cement plant, the heat required for solvent regeneration can be supplied by:

1. Dedicated natural gas boiler
2. Dedicated biomass or biogas boiler
3. Heat pumps – heat integration with the CO_2 capture process and CO_2 processing unit (CPU). The heat integration can be done with or without process modifications
4. Changing plant operating conditions
5. Major plant modifications, such as removing multiple stages of the preheater train

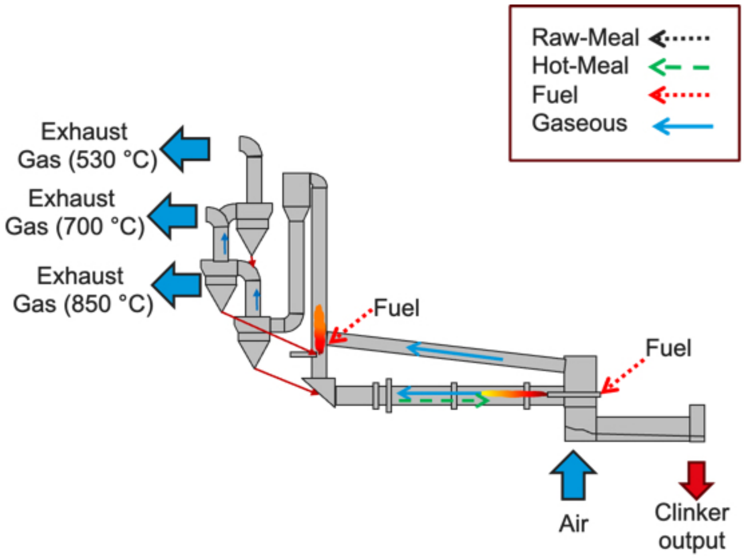

Figure 1: An overview of the temperatures at which heat is available for extraction when considering the modification of the preheater tower in the cement plant

In this work, a reference cement plant previously defined (Anantharaman et al. 2018) as a benchmark is analysed. Given the importance of moisture content in the raw material feed, four cases of raw material moisture content are considered, covering the range of moisture content in Europe. Two post-combustion solvent processes are also considered.

The five approaches to bridging the thermal gap, i.e., providing the missing heat, are listed above. They are modelled and integrated with the two post-combustion solvent processes and the cement plant. A thermodynamic analysis of the five approaches to bridging the thermal gap listed above offers insights into which method of supplying the additional heat required is suitable for varying moisture contents of the raw material. Furthermore, the analysis examines different electricity supply scenarios and their impact on net CO_2 avoided across the various cases.

Keywords: Solvent-based capture; process integration; heat pumps

References

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