Investigating the effects of different parameters on CO_2 capture performance for different Austrian industrial flue gases

Introduction

Intensified global efforts to decarbonize and transition to sustainable energy are dictated by the rapidly rising global energy demand of an increasing global population. Different industries, including cement, iron and steel, and chemical industries, have process-inherent emissions that cannot be easily avoided by other means, so-called hard-to-abate industries (Paltsev et al. 2021). In order to fulfill the net-zero target by 2050 (Sabatino et al. 2021), it is crucial to focus on these industries. One promising pathway to achieve this target is CO_2 capture. Depending on the process configuration, capture technologies are generally classified into post-combustion, pre-combustion, and oxy-fuel combustion systems. Among these, post-combustion capture is the most mature and widely implemented approach, particularly for retrofitting existing power plants and industrial facilities.

This study evaluates the effects of flue gas flow rate (FGFR) and CO_2 concentration on the absorber and stripper design for post-combustion CO_2 capture for different Austrian industrial hard-to-abate flue gases.

Method

Some of the most important factors affecting CO_2 capture efficiency are the solvent type and its flow rate. In this work, monoethanolamine (MEA) is considered as the solvent due to its numerous advantages and wide applications in the CO_2 capture systems. Moreover, the absorber is designed using rate-based calculation in Aspen Plus to reach high CO_2 capture efficiency across all FGFRs and CO_2 concentrations. The height and diameter of the absorption column are the main geometrical impact factors on the CO_2 capture efficiency. The reactions that participate in the CO_2 capture process through utilizing MEA as the solvent are (Nouri et al. 2025):

$$2H_2O \leftrightarrow H_3O^+ + OH^- \quad \text{Eq.1}$$
$$CO_2 + 2H_2O \leftrightarrow H_3O^+ + HCO^-_3 \quad \text{Eq.2}$$
$$HCO^-_3 + H_2O \leftrightarrow H_3O^+ + CO^{-2}_3 \quad \text{Eq.3}$$
$$MEAH^+ + H_2O \leftrightarrow H_3O^+ + MEA \quad \text{Eq.4}$$
$$MEACOO^- + H_2O \leftrightarrow HCO^-_3 + MEA \quad \text{Eq.5}$$

Table 1 summarizes the properties of the flue gases for different hard-to-abate industries in Austria. These industries are among the high CO_2-emitting industries in Austria.

Table 1. Properties of the flue gases for different hard-to-abate industries in Austria

Flue gas flow rate (kmol/hr)	CO_2 concentration in flue gas (%)	Industry (company name)
10268.6	17.8	Cement
3197	10	Waste incineration (WienEnergie)
55032	15	Refinery (OMV)
48000	26.6	Iron and steel (Voestalpine)
4430	17.8	Limestone

Results and discussion

This section presents results on the effects of varying FGFRs and CO_2 concentrations on the solvent flow rate, the absorber height-to-diameter ratio (HtD), and the reboiler duty, chosen to maintain a constant CO_2 capture efficiency of 88%.

Figure 1 illustrates the required solvent flow rate for each considered industry. In this analysis, the HtD for the absorber column is kept constant across industries to focus solely on the effects of the solvent flow rate at a constant HtD ratio.

Both increasing FGFR or CO_2 concentration requires higher solvent flow rates for maintaining capture efficiency. Moreover, it can be seen that the iron and steel industry clearly requires the highest solvent flow rate due to the high CO_2 flow rate in the flue gas, followed by the refinery (OMV).

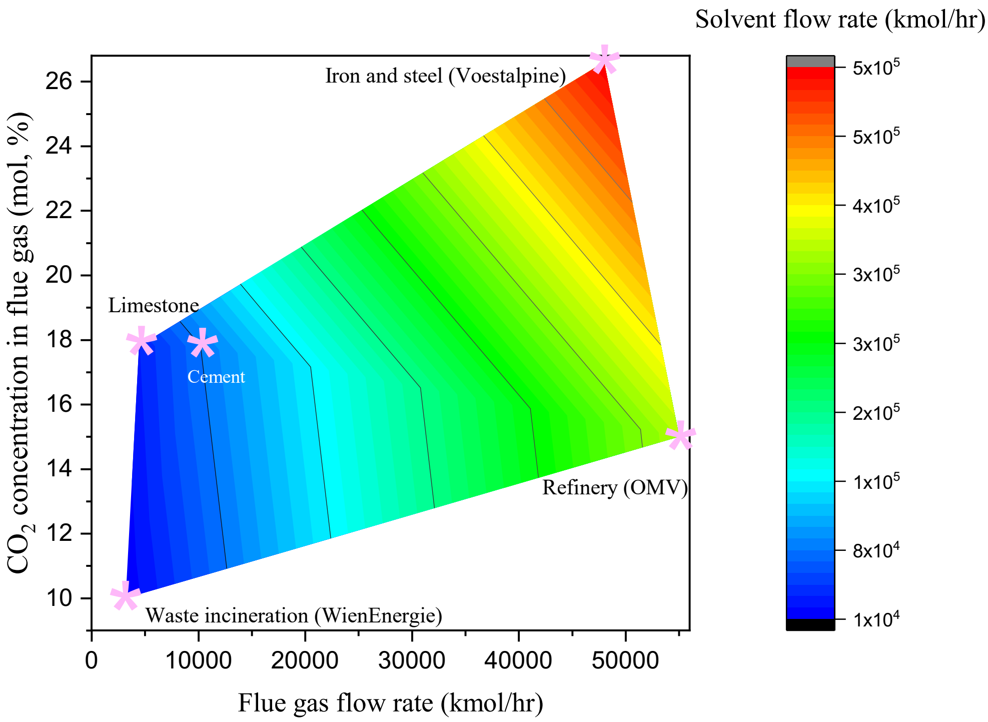

Figure 1. Required solvent flow rate for each industry to achieve a CO_2 capture efficiency of 88%,

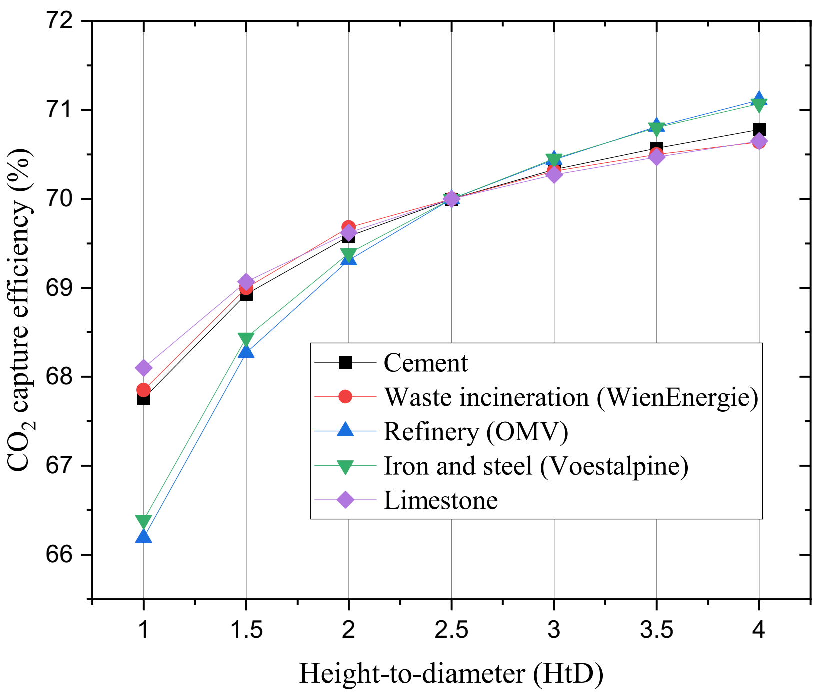

Figure 2. Effects of the HtD on the CO_2 capture efficiency of different industries

Figure 2 shows the effects of the HtD on the CO_2 capture efficiency of the industries; increasing the HtD of the absorber also increases the CO_2 capture efficiency. This increase at lower HtD values is sharp, and as HtD increases further, the slope decreases. This means that increasing the HtD can improve CO_2 capture efficiency at low speed by increasing it further. It should be noted that increasing the absorber size results in an increase in the equipment cost of this component. Although further increases in HtD can enhance CO_2 capture efficiency at low speeds, they can lead to high costs.

Therefore, it would not be cost-effective to make the absorber larger than the HtD of 4. At HtD equal 2.5, the CO_2 capture efficiency for the flue gases of all industries can reach 70%. Because the CO_2 flow rates in the iron and steel and refinery industries are much higher than those in other industries, their CO_2 capture efficiencies can vary more than those in other industries. It can be seen that at low HtD, iron and steel, and OMV have the lowest CO_2 capture efficiency. However, at the highest shown HtD, these industries can reach the highest CO_2 capture efficiencies.

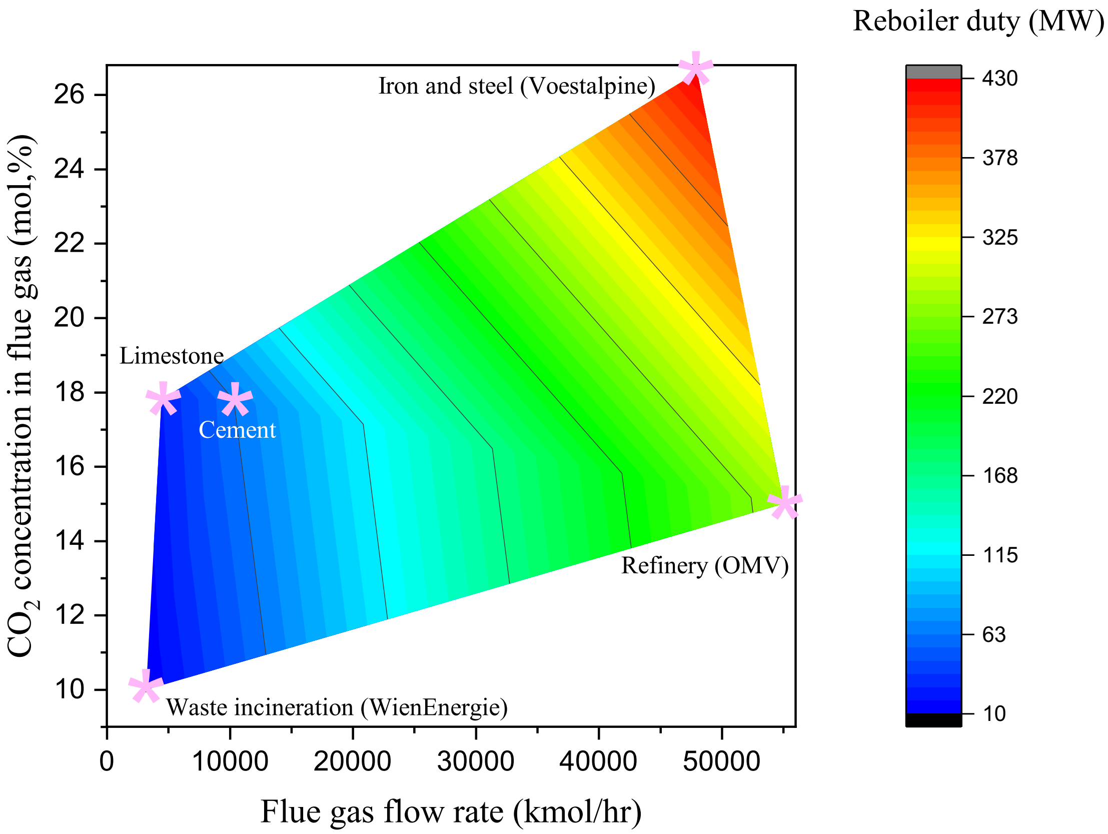

Figure 3. Required reboiler duty of the stripper for each industry

Figure 3 shows the required reboiler duty of the stripper for each industry. Iron and steel has the highest reboiler duty at 428.3 MW, followed by OMV at 285.7 MW. This is connected to the results shown in Figure 1, since increasing the solvent flow rate leads to an increase in the reboiler duty. Therefore, a higher CO_2 flow rate in the flue gas results in a higher solvent flow rate and reboiler duty. The stripper design regarding the reboiler duty is implemented considering that the geometry properties of the stripper remain constant.

Conclusions

In conclusion, there are several important factors that can affect the performance of the CO_2 capture subsystem for different industrial flue gases. This study evaluates the effects of flue gas flow rate (FGFR) and CO_2 concentration on the absorber and stripper design for post-combustion CO_2 capture for different Austrian industrial flue gases. The results for the HtD ratio reveal that it significantly influences the performance. However, there is an optimal economic design point that should be aimed for. For a further efficiency increase, other parameters play an important role. By adjusting the solvent flow rate, the same CO_2 capture efficiency for different industrial flue gases can be achieved. As the solvent flow rate increases, the reboiler duty of the stripper increases as well, and based on the results, the refinery (OMV) and iron and steel (Voestalpine) require the highest solvent flow rates and reboiler duties.

References

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