Heat integration of a novel system for CCS at an oil refinery

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Keywords: Post-combustion carbon capture; industrial excess heat utilization

1. Introduction

Implementation of CCS in industrial applications has gained increasing attention the last years. While the power sector currently lacks suitable incentives to switch from fossil fuels to renewable alternatives such as wind or solar, the industrial sector struggles with a more difficult switch since the carbon is sometimes inherent in their processes or a part of their product. Oil refineries could therefore be an example of an industrial sector that is going to be fossil based on a medium to long term basis, and would therefore also be an eligible target for CCS.

The industrial sector has access to excess heat, where the main part of the excess heat is available at low temperatures. Using this low grade heat for CCS with traditional amines such as MEA leads to high specific heat demands and low pressure \cite{1}. This abstract is a part of a cooperation with Lund University which is developing a novel amine system where such problems are not as severe \cite{2}. More information on the process can be found in Karlsson and Svensson’s abstract to the conference (PCCC4) with the title “Regeneration of Non-Aqueous Precipitating Amine Solvents”. Several reports have concluded that the largest cost in the CCS process is attributed to the capture and, in the case of post-combustion CCS, especially to the regeneration of the amine. Industrial excess heat could thus prove to significantly lower the cost for CCS, which is main a barrier for large-scale implementation. There are many cost estimates of post-combustion systems \cite{3–7}, but to the authors’ knowledge only two that have taken excess heat recovery into consideration \cite{5,7}. The conclusion from these studies is that utilization of excess heat does make the CCS process less expensive. Investigating how to best utilize excess heat to decrease the cost of post-combustion CCS in the Swedish industrial sector, which includes steel plants, oil refineries, petrochemical plants, and pulp and paper mills, for is therefore the main objective of this project. This paper summarizes some important findings from of a case study analysis performed at an oil refinery.

2. The capture process

The capture process considered consists of a sterically hindered amine, 2-amino-2-methyl-1-propanol (AMP) in the organic solvent N-methyl-2-pyrrolidone (NMP). In comparison to aqueous solutions of AMP, organic solutions forms a less stable carbamate which enables the possibility of desorbing CO\textsubscript{2} at lower temperature. The AMP-NMP system is capable of desorbing CO\textsubscript{2} at 70-90°C (T\textsubscript{Reb}) \cite{2,8} and is therefore a more favorable recipient of industrial excess heat.
excess heat compared to for instance MEA (aq) and piperazine (aq), both with a standard T_{Reb.} of approximately 120°C.

3. Heat integration with a complex oil refinery

The case study refinery is a complex oil refinery (including a steam reformer for hydrogen production) that emits approximately 1.8 Mt CO₂/y from the 4 main chimneys. In this study, excess heat from the oil refinery processes is assumed to be utilized to perform partial capture of as much CO₂ as possible. Given the uncertainty of future excess heat availability at the refinery, two significantly different cases are considered. In the first case, it is assumed that the refinery heat exchanger network is retrofitted so as to achieve maximum energy recovery (MER). In this case, availability of excess heat can be estimated using the process Grand Composite Curve (GCC). In the second case, the current cooling profile is considered, represented by the process actual cooling load curve or ACLC. The two situations are depicted in two T/Q diagrams in Figure 1. The diagrams are zoomed in for clarity.

With decreasing T_{Reb.}, the specific heat demand increases while the desorption pressure decreases, but T_{Reb.} also has implications on the amount of industrial excess heat that can be utilized [1, 9]. Earlier work has shown that decreasing T_{Reb.} is not always beneficial if the goal is to avoid as much CO₂ emissions as possible even if the amount of excess heat that can be utilized increases with decreasing temperatures [1]. Lower pressure levels increase the compression work requirements, leading to increased power consumption. The process’ carbon footprint depends on the assumed carbon intensity of power generation. There is also an economic trade-off to be made when decreasing T_{Reb.}. Equipment needs to be larger and the operating costs (e.g., cost for compression) increase.

Two temperatures are currently being investigated with respect both to specific heat of regeneration and the resulting pressure of the outgoing CO₂; 75°C and 90°C. Figure 1 also contains vertical lines that show how much excess heat that can be extracted at these temperature levels (ΔT_{system}=20 K).

Figure 1: T/Q diagrams of a maximum energy recovery (MER) heat exchanger network and the current cooling utility network (ACLC).

Figure 1 shows that, unlike regular amines with standard desorption temperatures of at least 120°C, the AMP-NMP system could utilize excess process heat even for the case where it is assumed that the heat exchanger network is rebuilt to achieve MER. If the amount of excess heat is not sufficient to capture all the CO₂ present in the flue gases at T_{Reb.} of 90°C, a tradeoff of decreasing T_{Reb.} and thereby enabling the possibility of using more excess heat but with decreased pressure of the outgoing CO₂ is activated. As mentioned above, the assumed power generation technology and the way of valuing excess heat utilization on a CO₂-basis plays will have a major impact on the tradeoff. To make a proper assessment of the CO₂ value of excess heat, the alternative uses for excess heat must first be evaluated.

Ongoing work during the spring of 2017 will provide more detailed data about the specific heat demand and resulting pressure levels of the AMP-NMP process. Preliminary results, however, indicate that all CO₂ from the flue...
gases can be captured if assuming the current utility network, ACLC. The same preliminary results indicate that the excess heat is not sufficient when having a MER network. This means that there is an economic tradeoff between doing energy efficiency measures and being able to capture the same amount of CO₂ as is currently possible.

4. Techno-economic assessment

Conceptual designs of the heat collection systems will be presented for both the MER and the ACLC network cases in order to estimate the cost for heat supply through excess heat recovery at both 75°C and 90°C. The results from the heat demand study will be used to finalize these conceptual designs. The heat exchanger costs estimations have been performed using standard methods available in handbooks, whereas the piping cost estimates have been made with the aid of refinery experts [10,11].

The total cost (CAPEX and OPEX) for the heat supply via a heat collecting network will be compared to the cost associated with supplying the same amount of heat with a biomass boiler for various prices of biomass.

5. Acknowledgement

This work is funded by the Swedish Energy Agency.

References