HSLU Hochschule Luzern

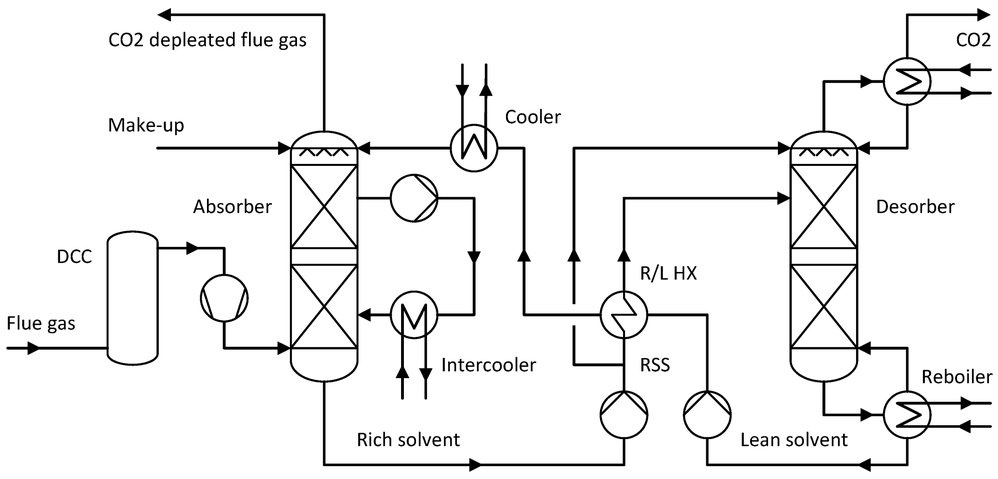
Engineering & Architecture
Master of Science in Engineering
Energy & Environment

Master's Thesis

Negative Emissions and Power-to-X (P2X)

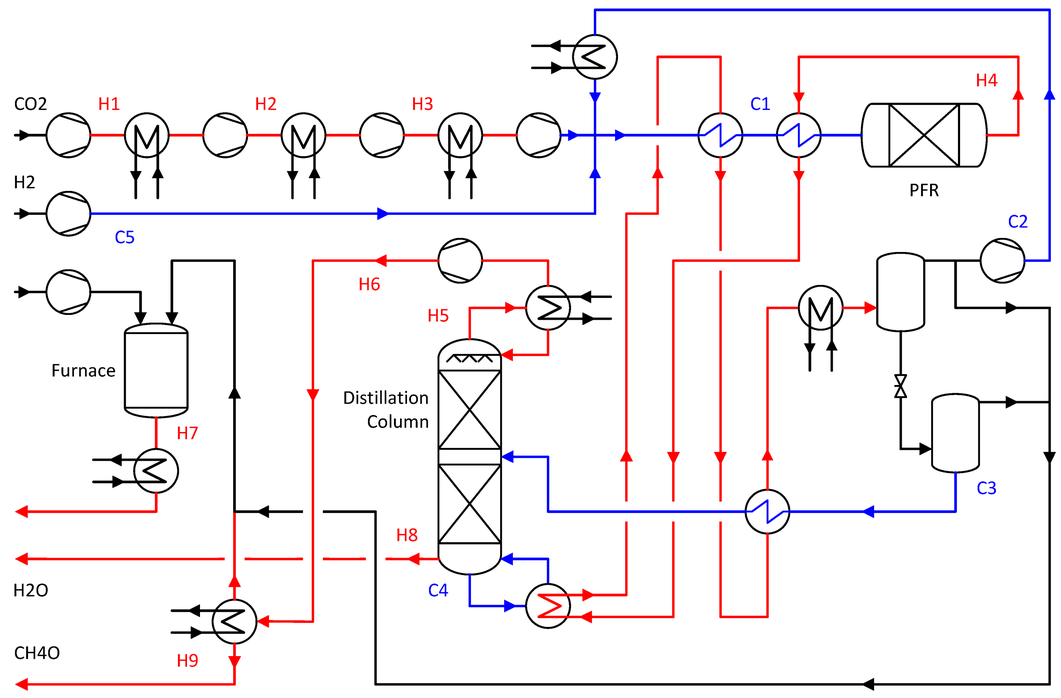
Simulation, Integration and Evaluation of Carbon Capture, Liquefaction and P2X Processes

Comparison of various Carbon Capture Processes:

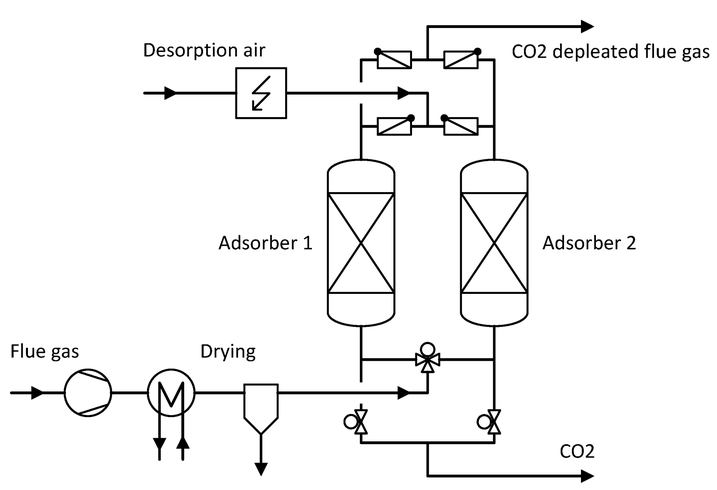


Example 1: Carbon capture by absorption using amine scrubbing

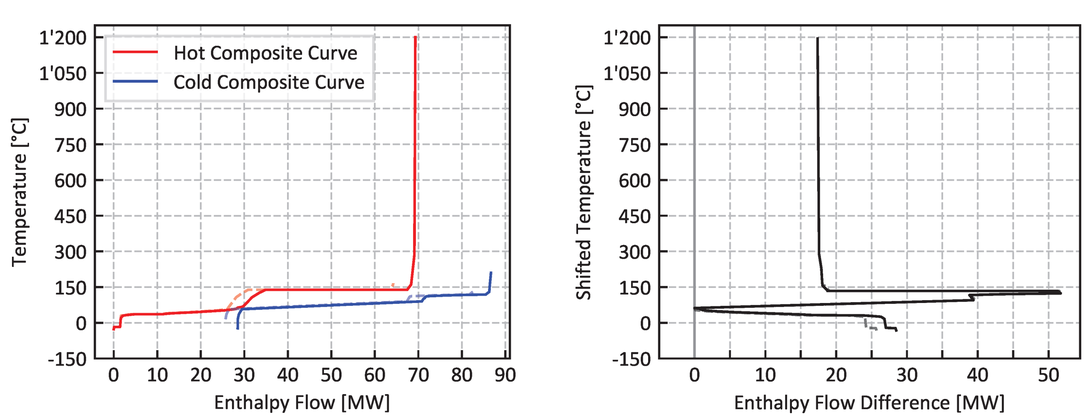
Thermal Integration of Power-to-X Technologies:



Methanol synthesis as a sub-process of Power-to-Methanol



Example 2: Carbon capture through adsorption processes



Integration of Power-to-Methanol into a waste incineration plant:
Influence on composite curves and grand composite curve

Problem Statement

As part of its energy strategy, Switzerland is aiming to reduce its greenhouse gas emissions to net zero by 2050. In order to achieve this goal, the expansion of renewable energies and efforts to increase energy efficiency must be driven forward.

The pinch method is a proven instrument for reducing CO_2 emissions from energy systems and processes. In addition to the reduction of emissions, however, the permanent capture and storage as well as the reuse of CO_2 is also necessary, as a large amount of CO_2 emissions from sectors such as agriculture, the cement industry or waste incineration are difficult to avoid.

Inspired by the SFOE project «PICC: Process Integrated Carbon Capture - Design and Evaluation» which is being carried out by the HSLU, the topics of negative emissions, process simulation/integration and Power-to-X were considered in combination in this thesis. The aim of PICC is to investigate how carbon capture plants can be integrated into energy generation systems with biogenic fuels at optimal cost.

In addition, the conditions under which Power-to-X makes sense on site will be investigated. This thesis supports and supplements the work within the PICC project in various areas.

Procedure

Various carbon capture processes suitable for retrofitting energy generation plants were compared. It was investigated whether, in addition to the current benchmark process of absorption using amine scrubbing, other processes will become established in the future.

In the second part, the use of DWSIM as a chemical process simulator was verified. For this purpose, an extensive CO_2 purification and liquefaction plant of the industrial partner and CO_2 separation by means of amine scrubbing were simulated.

Power-to-X technologies and their thermal integration were also examined in more detail. In addition to hydrogen electrolysis, downstream processes such as methanation and methanol synthesis were investigated.

Results

The various processes for carbon capture were evaluated on the basis of selected criteria and preferred areas of application were identified. DWSIM was suitable for the simulated CO_2 purification and liquefaction plant. However, when modeling an absorption process with amine scrubbing for CO_2 capture, the implemented Amine Property Package was not yet convincing. The thermal integration of the various Power-to-X technologies in the case study of a waste incineration plant turned out to be quite similar in each case, as the electricity demand of electrolysis led to very small plant sizes and therefore comparatively low thermal process requirements.

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