HSLU Hochschule Luzern

Technik & Architektur
Institute of Mechanical Engineering and Energy Technology

Energy and Environment

Development and Evaluation of an Amine Scrubbing System for Atmospheric CO₂ Capture: A Feasibility Study for Decentralized Applications

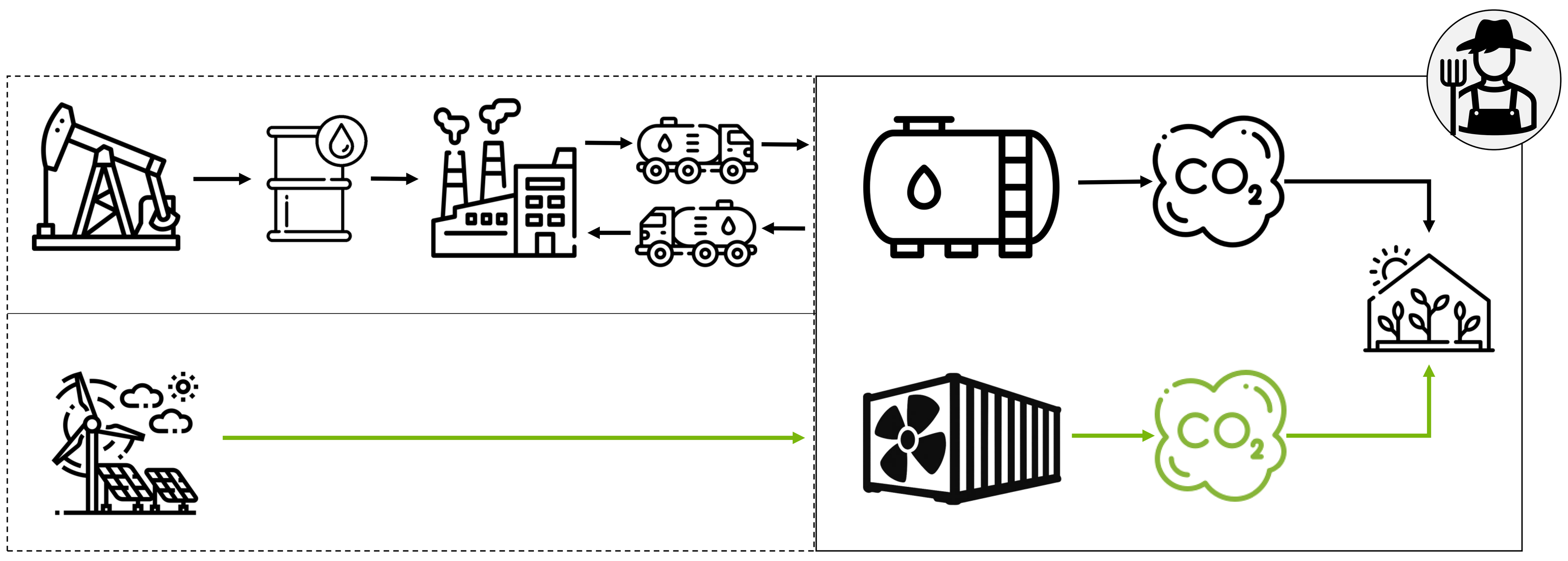

Figure 1: Illustration of the current supply chain and its fossil dependency versus the proposed solution in this thesis.[1]

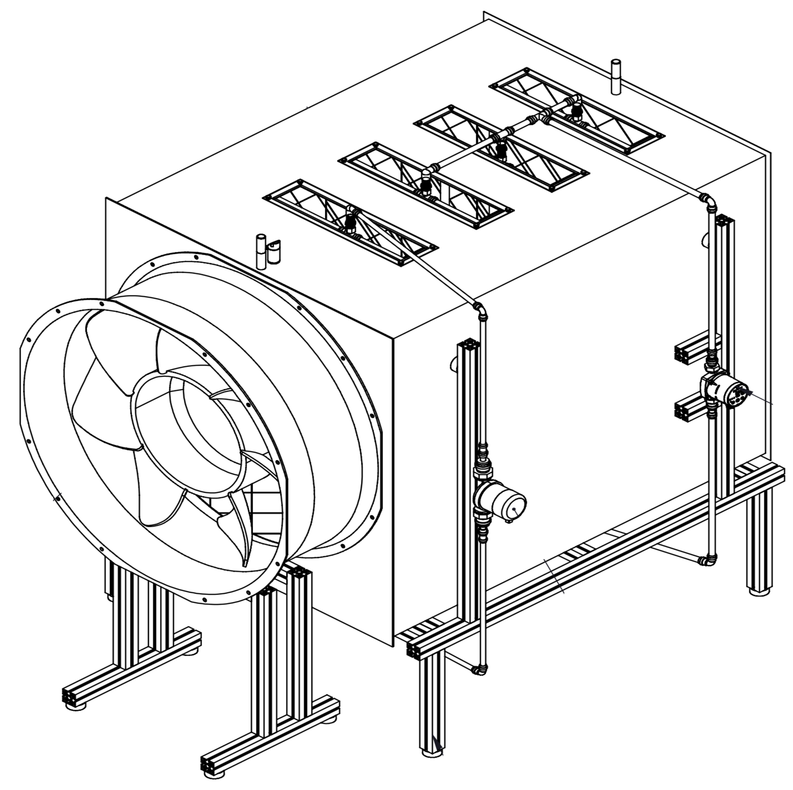

Figure 2: Absorber contactor design based on cooling tower and packed-colum theory.[2]

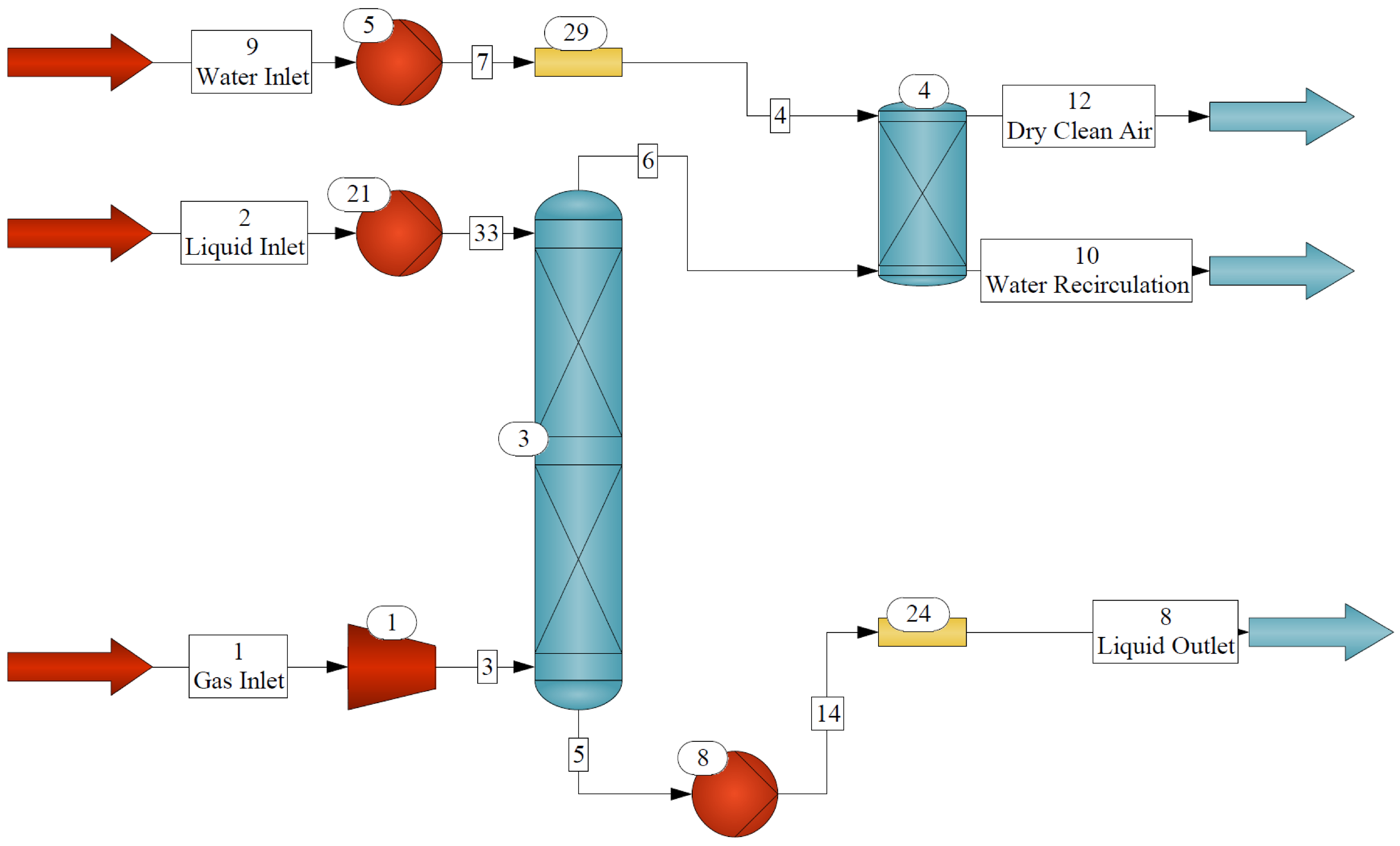

Figure 3: Absorber contactor simulation in ChemCAD including all components required to produce a CO_2 and moisture reduced stream at the outlet.[3]

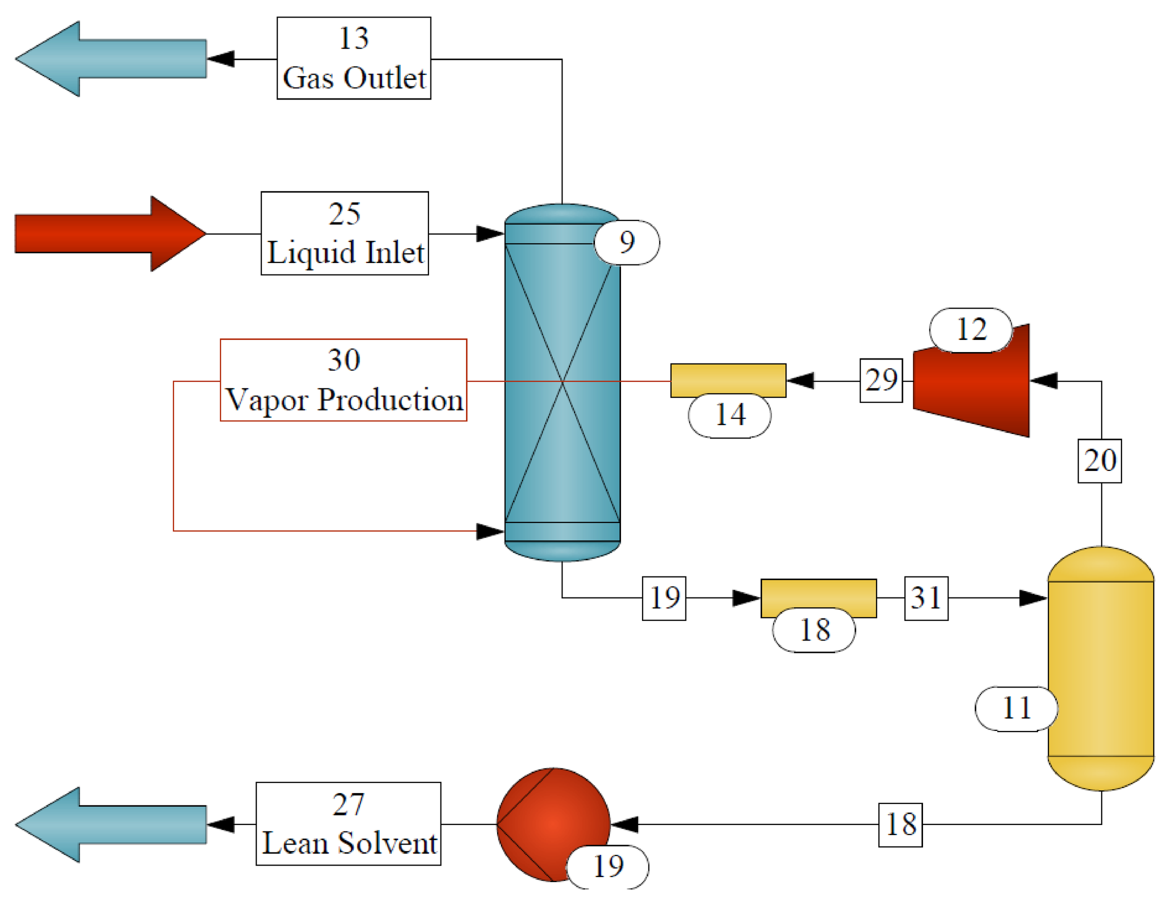

Figure 4: Desorber column simulation in ChemCAD including all components to strip CO_2 from the solvent.[4]

Problem Description

The clean-energy transition demands practical methods to decarbonize sectors that still depend heavily on fossil fuels. Greenhouse horticulture is one such sector, relying on CO_2 enrichment to stimulate plant growth. This study seeks to develop a sustainable, flexible, and cost-competitive solution that can be easily retrofitted into existing greenhouse operations.[1]

To reach this goal, the project builds on earlier research conducted at HSLU, where CO_2 absorption with liquid sorbents was successfully demonstrated in a counter-current packed column designed according to established point-source capture theory that was adapted for diluted concentrations.

To guide the development of this technology, the project adopts two key targets: a production rate of 10 $kgCO_2\ h^{-1}$ and an energy demand below 3 $kWh\ kg^{-1} CO_2$, both regarded as essential for economic viability.

Solution Concept

The prototype consists of two modules: a hybrid cooling-tower/packed-column absorber that maximizes gas–liquid contact while keeping pressure drop low[2] and a desorber simulated in two configurations, (I) a conventional reboiler stripper and (II) an integrated heat-and-mass exchanger that releases CO_2 via coordinated vacuum- and temperature-swing regeneration.

Results

Process-modelling with ChemCAD shows that a three-stage, cross-flow absorber [3] sized for 10 $kgCO_2\ h^{-1}$, combined with an integrated heat-and-mass-exchanger desorber [4], achieves a specific energy consumption of 2.2 $kWh\ kg^{-1}CO_2$, 21% less than the initial design based on conventional reboiler theory.

Structured packing, vacuum pumps, electric heaters and the respective detailed engineering have been fully specified and sourced, translating the simulation into build-ready hardware.

A product-oriented work-breakdown structure and detailed bill of materials now lock pilot CAPEX at ≈ 61 kCHF. This unit is sized to deliver continuous CO_2 for a 0.5 ha greenhouse area. Forthcoming tests will benchmark energy use and throughput to confirm the concept's economic case and increase the understanding of the solvent's performance.

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