Techno-economic assessment of carbon capture and utilization concepts for a CO2 emission-free glass production

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Abstract

Climate neutrality until 2045/50(1) is a considerable challenge for the European industry, and a particularly enormous one for the glass industry. The main CO2 emissions of the glass industry (around 22 Mt per year in Europe(2)) originate primarily from two sources, fuel-related emissions, and process-related emissions caused by carbonatic batch ingredients. Although, fuel-related emissions can be avoided by, *e.g.*, the implementation of hydrogen combustion or all-electric melting (AEM), these approaches do not address process-related emissions. Moreover, the knowledge on hydrogen-based glass production is still limited, with open questions regarding refractive materials and redox behavior of the melt. AEM, on the other hand, is limited to comparably small tonnages (less than 250 t saleable glass per day) and cullet contents in the batch below 60 %. Additionally, since the redox state of AEM glass is difficult to control, this process is unsuitable for redox-sensitive amber coloring. The process-related CO2 emissions could theoretically be avoided by replacing carbonatic batch ingredient with, *e.g.*, hydroxides. However, the production of hydroxides requires often geological carbonates as raw materials (lime, dolomite), or is very cost- and energy-intensive (NaOH, via chlor-alkali process).

In contrast, implementation of Carbon Capture and Utilization (CCU) with e-fuel synthesis via hydrogen from electrolysis addresses both emission sources without constraining the glass production. In our study, we perform a techno-economic assessment on the implementation of different CCU cycles into the glass production. Here, the CO2-rich flue gas stream (above 95% dry gas composition for oxy-fuel combustion) is purified, and then converted into a storable fuel with on-site generated hydrogen. The CCU cycle is closed by using the synthesized e-fuel to feed the combustion in the glass furnace. Through the implementation of this CCU concept, the surplus CO2 coming from the carbonates in the batch is converted into a saleable product, while no emissions are released into the atmosphere. To quantify the viability of CCU cycles in the glass production, we evaluate the technological and economic advantages of several state-of-the-art technology chains and analyze the influence of different electricity price scenarios on the production cost. Suitable technologies, including gas cleaning, fuel synthesis and hydrogen production, are simulated in Aspen Plus® and converted into a Python model. Subsequently, the techno-economic performance is estimated with the DLR in-house tool TEPET. As regenerative grid electricity prices significantly fluctuate over time, an algorithm was developed to optimize the plant's electricity purchasing, based on the

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German day-ahead market. With a combination of over-dimensioning the electrolyzer and variation of hydrogen storage capacity, periods of high electricity prices are avoided and the overall electricity cost is minimized.. Through this techno-economic assessment, we enable an objective and transparent comparison of multiple plant layouts for different scenarios – and with that, the possibility to select the most suitable solution for any glass production plant.

This project is funded by the European Union – NextGenerationEU and the BMBF as project *01LJ2005A* in the KlimPro call.

(1) https://www.bundesregierung.de/breg-de/themen/klimaschutz/climate-change-act-2021-1936846 https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

(2) https://cinea.ec.europa.eu/news-events/news/how-life-reducing-emissions-glass-production-2022-03-16_en

Keywords: Techno, economic assessment, CO2, neutral glass production, fit for 55, glass production process, Carbon Capture and Utilization