Technical and environmental comparison of diverse valorization routes of CO_2 as ethanol under a simulation approach

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CO_2 capture (CC) and utilization technologies are considered in different carbon-neutrality and climate mitigation scenarios to provide a complementary solution to energy efficiency/sobriety and renewable energies implementation. The main challenges of these involve their adaptation, optimization and scale-up for diverse applications and industries. Moreover, the choice of CO_2 sources and technologies should be thoroughly based on an analysis of the potential environmental impacts, to ensure the benefic effect on climate. This work presents a technological and environmental analysis of different routes for ethanol production from CO_2, comprising the CO_2 capture and ethanol synthesis. First, various CC technologies, currently at different TRL levels, were modeled and simulated (ProSimPlus®): chemical absorption (CA) membrane separation (MS), cryogenic separation (CS), and high-pressure water scrubbing (HPWS). Two CO_2 sources were considered: biogas and cement flue gas. Then, three synthesis processes were modeled and simulated: a chemical process using syngas obtained from CO_2, biological synthesis from syngas, and fermentation of CO_2 and H_2. Different value chains of converting CO_2 into ethanol were considered by combining the CO_2 sources, CC technologies and synthesis routes, and were assessed from the environmentally by using the Life Cycle Assessment (LCA) methodology. Figure 1 illustrates the examined scenarios. Technical performances (in terms of product formation and energy requirements) and the life cycle inventory (for LCA) were built up based on the calculated mass and energy balances from the simulations. The ReCiPe Midpoint method was used as impact calculation method. Concerning CC, based on biogas, membrane separation (MS) demonstrated the best overall environmental performance with low energy consumption. On the other hand, results from the ethanol synthesis simulations shown that the value chain producing ethanol from CO_2/H_2 provided the lowest environmental impacts and energy consumption when compared per 1 kg of ethanol produced because this is the scenario producing the largest amount of ethanol. Although encouraging, these results need to be proven experimentally at large scale.

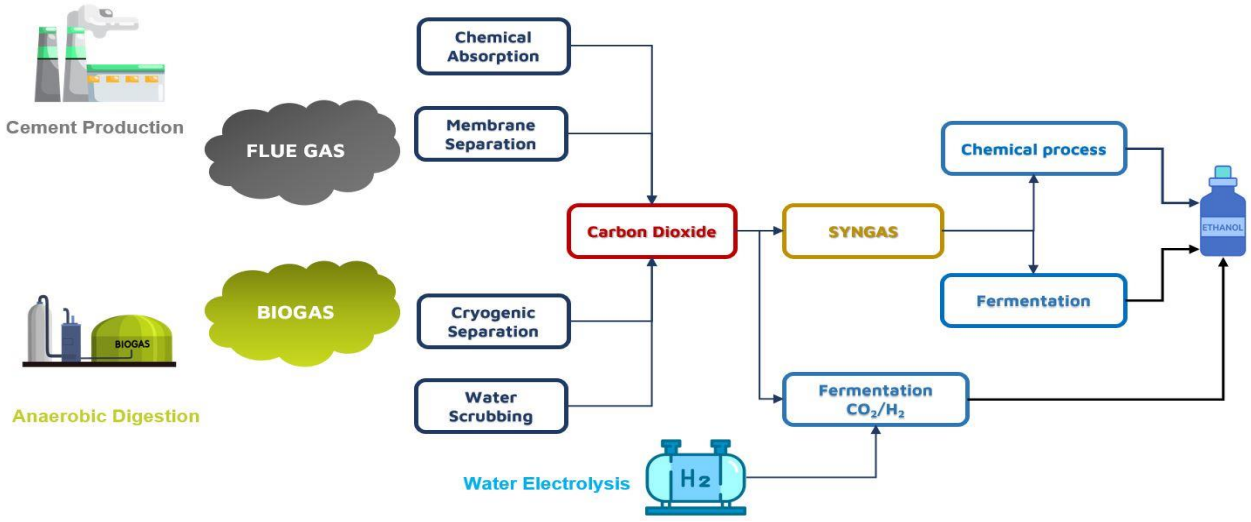

Figure 1. From CO_2 Source to Capture Technology and End-Use Application

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