Valorisation of CO_2 from biogas plants: circularity in agro-economy

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Abstract

As methane has been establishing itself as a primary energy source, to obtain it from renewable carbon feedstock rather than to extract it as natural gas is by far more appealing: biomass-generated methane is an efficient power generation mean with a virtually closed CO_2 cycle, accompanying the transition towards a zero-carbon energy future. Biogas however contains large amounts of CO_2, to be at least separated to exploit biomethane, and possibly valorised.
A first option is CO_2 hydrogenation to methane, also promising to transform an energy vector that is uneasy to handle (green H_2) into a valuable and worldwide-distributed fuel and feedstock (CH_4). A "power-to-gas" framework could then help to overcome the drawbacks of H_2 as an energy storage medium and to increase the continuity and general availability of different intermittent renewable energy sources. This flexibility offers also additional possibilities for the downstream use of biogas, which may be richer in hydrogen or methane according to the process operation, even if these conditions might not fit the distribution networks nearer to the biomass-treating site.
Different options for the efficient direct conversion of CO_2 and H_2 into CH_4 (Sabatier reaction) are here explored both experimentally and through process design. A key issue is the strong exothermicity of the reaction. Our research explores the use of water vapour, added on purpose to the reactor as a thermal vector and later condensed. The simplest and most economical reactor arrangement is composed of a certain number of adiabatic beds (up to five) with intercooling. Some options propose cooled stages, but they are more expensive. Alternatives may be fluidized-bed reactors that allow better temperature control, but they lead to incomplete conversion and are more difficult to scale-up. The possibility to use the methane already present in biogas as diluent (i.e. thermal vector to control the exothermicity) is also considered, offering the additional advanrage to eliminate the otherwise needed and expensive CO_2 capture step.
Another option to valorise the CO_2 recovered from biogas is the transformation into urea, carbonate and bicarbonate through ammonia-based capture. This concept fits a circular view of CO_2 recovery and valorisation returning in the same environment (as fertiliser) this waste product.

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