Carbon Dioxide Utilization Technologies

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Abstract

This PEP report presents the technoeconomic analysis of three developing technologies that use atmospheric CO_2 and H_2O (steam and water) as raw material to produce syngas (H_2 and CO mixture) and synthetic natural gas (methane). The analyses are presented in Chapters 5, 6, and 7 under the following headings:

- Conversion of CO_2 to syngas for a Fischer-Tropsch fuels plant by co-electrolysis of CO_2 and steam (Sunfire GmbH)
- Conversion of CO_2 to methane by co-electrolysis of CO_2 and steam (Sunfire GmbH)
- Production of methane from industrial CO_2 emissions and electrolytic H_2 from water (Hitachi Hozen Inova/ETOGAS)

Different aspects of the technologies have been analyzed and the results of these analyses are presented in descriptive, tabulated or diagrammatic formats, depending on the feature of the technology described. Main elements of the technology analyses include selection and statement of assumptions/bases for process design, process design details (process description with a complete statement of process operating conditions, material and energy balance, process flow diagram, process discussion, process equipment listing with sizes, utilities consumption, capital costs, and production costs. All processes use electricity, which is generated from renewable energy sources (solar or wind).

Syngas (Chapter 5) is produced as feed material for the Fischer-Tropsch process, whereas the synthesis natural gas (Chapters 6 and 7) is produced to be used as a fuel. A notable thing about the analyzed technologies is that the electricity used in the processes is produced from renewable sources of energy (solar energy in our case). CO_2 and H_2 are obtained from atmospheric air/flue gas and steam/water electrolysis, respectively. These CO_2 utilization technologies are currently in the initial stages of development and have been tested on pilot or mini-plant levels; we have carried out technoeconomic evaluation of those technologies at higher (projected) capacities, thus, incorporating the likelihood for cost reduction due to economies of scale.

Potentially, the CO_2 utilization technologies offer an enormous market. For example, in 2018, approximately 330,000 million tons of global energy-related CO_2 was emitted. Not surprisingly, the three largest industrial nations—China, India, and the United States, together accounted for more than 50% of that. In comparison, the total global merchant and captive CO_2 market in 2018 was estimated at only 230 million metric tons, which is about 0.7% of the global emissions. Hence, as far as the availability of raw material (CO_2 and water) is concerned, there is an abundance of it (CO_2 atmospheric concentration in 2018 was about 408 ppm). Solar and wind energy are also freely available in many regions of the world for a major period of time. Hence, as far as basic imperatives and scope for the expansion of those technologies are concerned, they are enormous. Proponents of the CO_2 circular economy notion consider development and expansion of such technologies as the first and most important step towards the realization of the goal of a CO_2 circular economy.

Besides economic utility, CO_2 utilization via conversion to useful products also offers potential opportunities for control/reduction of CO_2 emissions to the atmosphere, which may not be of perceptible magnitude initially, but could bring tangible results over time. While attempts to limit CO_2 emissions by reducing the burning of fuels, conducting more effective collection and sequestration of CO_2—have been going on for quite some time now, the evolving CO_2 utilization technologies (also referred to as CO_2 recycling) can open a vast avenue to use atmospheric CO_2 in the development of products and services. Such potential of these technologies is capturing serious attention of the industry, investment communities, and some governments, which are interested in mitigating climate changes from the effects of greenhouse gases and being supportive of a circular economy. Five key categories of CO_2-derived products and services have been the focus of studies and technoeconomic analyses. These categories include fuels, chemicals, building materials from minerals, building materials from wastes, and CO_2 used as an enhancer of yields from biological processes. New pathways involving chemical and biological conversion of CO_2 to aforementioned products are being studied.

We believe that the abovementioned CO_2 utilization technologies, in their present condition, may be useful under special circumstances (e.g., in those places where fossil fuel is very expensive or not available at all). Also, their use is likely to remain limited to small-sized local applications—at least in the short- to medium-term future. The reason for this is despite all the potential benefits of those technologies as outlined above, there is presently an unfavorable aspect of those technologies that needs to be improved for their application to be picked up on a wider scale. And that aspect is their high capital and production costs in relation to the corresponding cost parameters for the same materials produced from conventional technologies. To some extent, that is quite understandable. The technologies are in the initial stages of development/commercialization. The plant and equipment sizes are very small from an industrial point of view. Hence, their costs (especially of CO_2 capture plant, electrolyzer units, and electricity costs) are too high. The costs are likely to reduce as plants are built in larger sizes. And lastly, but very importantly, active regulatory support of governments and more liberal funding are needed. Public response and acceptance of those low-carbon products (possibly at higher prices) will be very helpful towards creating early markets for the CO_2-derived products with verifiable climate benefits.

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