Analysis and comparison of sustainable ethylene production processes

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Ethylene is one of the most widely produced and commercially important organic chemicals, used as a fundamental building block in polymer industry or specialized chemistry, or being used as a final product. Currently, the majority of ethylene is produced via the steam cracking of naphtha or ethane: a process that is highly energy-intensive and contributes extensively to greenhouse gas emissions. As the demand for ethylene continues to grow, the environmental impact of its production becomes increasingly significant rising the need for sustainable alternatives. In response to these concerns, a range of advanced production methods have emerged, including biogas conversion to syngas and Fischer-Tropsch synthesis, catalytic dehydration of bioethanol, and direct electrochemical reduction of carbon dioxide to ethylene. Their implementation could play a crucial role in decarbonizing the chemical industry and advancing a circular carbon economy. Inside this context, this work focuses on the design with economic and environmental analyses of a sustainable ethylene production process using biogas as a feedstock and combing the steam methane reforming with partial oxidation and Fischer-Tropsch synthesis. This study employs process modelling in Aspen Plus software. Several process configurations, including varying levels of electrification and heat recovery strategies are considered to select the solution that reduces emissions, enhances energy efficiency, and maintains economic feasibility, thereby providing a pathway toward a more sustainable, industrial-scale ethylene production. Key findings indicate that electrification of the process, especially when powered by renewable energy sources, significantly lowers carbon dioxide emissions, up to 90% compared to conventionally fossil-based configurations. While electrification increases operating costs due to higher electricity costs, the integration of advanced heat recovery technologies, including high-temperature heat pumps, offers a promising strategy to compensate these costs. The lowest ethylene production cost is achieved in conventionally powered scenarios with optimized waste heat reuse, however, with a cost of significantly higher carbon dioxide emissions. In contrast, the production powered by renewable electricity with heat reutilization increases the price only by 7%. In case of heat pump, the price rose only by 3%. It is a low cost considering that ethylene is produced with significantly lower carbon footprint. Compared to the literature, production costs are in line with other studies while electrified systems can ensure a lower environmental impact compared to the conventional route [1,2].

Keywords: *decarbonization, ethylene, process simulation, heat integration, carbon dioxide emissions*

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