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Techno-economic comparison of syngas and CO_2 sources for sustainable methanol synthesis

Aim

This thesis aims to conduct a systematic comparison for different syngas production pathways and CO_2 sources in methanol synthesis [1]. Through detailed process simulation and analysis, the study will evaluate energy efficiency, carbon footprint, and economic viability of various combinations, including electrolysis-based routes with different CO_2 capture options (point-source vs. direct air capture), dry reforming of methane, and other emerging technologies. The goal is to identify optimal solutions for different regional contexts and resource availability.

Justification

Recent studies have demonstrated that methanol production using electrolysis-based hydrogen and captured CO_2 can achieve significant emission reductions compared to conventional routes [2]. However, this pathway relies heavily on abundant renewable electricity, which may not be available in all regions. The source of CO_2 also significantly impacts overall process sustainability, with options ranging from industrial point sources to direct air capture. Alternative approaches such as dry reforming of methane [3] could provide complementary solutions for different geographical and economic contexts.
A systematic comparison of these alternatives, considering life cycle assessment and economic feasibility would provide valuable insights for future technology deployment. The analysis would help identify the most promising pathways depending on local conditions and resource availability.

Program

1. Literature review on alternative syngas production technologies, CO_2 capture methods, and their integration with methanol synthesis.
2. Process simulation of selected pathways using Aspen Plus or HYSYS:
    - Electrolysis-based routes with different CO_2 sources.
    - Dry reforming of methane.
    - Other promising alternatives identified from literature
3. Comparative assessment of different pathways considering technical, economic, and environmental aspects.

The research will leverage established process simulation tools to provide practical insights for technology selection and implementation.

1. Mäyrä, O. and K. Leiviskä, Chapter 17 - *Modeling in Methanol Synthesis,* A. Basile and F. Dalena, Editors. 2018, Elsevier. p. 475-492.
2. Mynko, O., et al., *Cradle-to-gate life cycle assessment of light olefin production via methanol-to-olefins (MTO) route using steel mill off-gases as carbon source*. AIChE Annual Meeting, 2024.
3. AlHumaidan, F.S., et al., *Blue hydrogen: Current status and future technologies. Energy Conversion and Management*, 2023. 283: p. 116840.