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Dynamic Simulations of an Integrated CCU-Electrolyser System

Aim

- Design and optimization of integrated CO_2 hydrogenation (methane or methanol) – electrolysis process to match intermittent renewable energy supplies.
- Analyse the energy and mass balances of a CCU-electrolysis system, optimize operation of units for various power curves (e.g. Europe, Africa, Middle-East, etc.).

Justification

To reach climate neutrality by 2050, Belgium and the rest of Europe must transition to a sustainable, affordable and secure energy system. A complete roll-out of intermittent renewable energy sources (RES) raises questions about the security of energy supply and grid stability. In the future energy system, energy molecules take on an important role to store and transport renewable energy. Green hydrogen is an energy molecule derived from water- or steam electrolysis, but is far from optimal for storage and transport. CO_2 hydrogenation produces CCU molecules (CH_4, CH_3OH, olefins) that are much easier integrated in the current infrastructure. By smart process integration, the reaction heat from exothermic CO_2 hydrogenation reactions can be used to significantly reduce the enthalpy cost of electrolytic water splitting.

The intermittency of RES requires novel dynamic process models, and severely impacts investment decisions. While low-temperature electrolysis allows flexible operation, the more energy-efficient high temperature electrolysis and the CO_2 hydrogenation reactions are more difficult to switch off. Process couplings between electrolysis and hydrogenation further complicate optimal process design. Depending on the solar irradiance and wind power availability, the optimal system may look very different. For example, the dimensions of a H_2 and CO_2 storage tank must be sufficiently large to provide the buffering capacity required during low power availability and allow the reactors to keep running, while the electrolysers and distillation system relies on steam produced by the exothermic hydrogenation reaction. Summarizing, the design of integrated CCU-electrolyser systems depends strongly on the performance of the electrolyser and CO_2 hydrogenation reactor, the possibilities for heat integration, and the power curve characteristics. To build this dynamic CCU-electrolyser model, MatLab (Simulink) programming tools will be utilized.

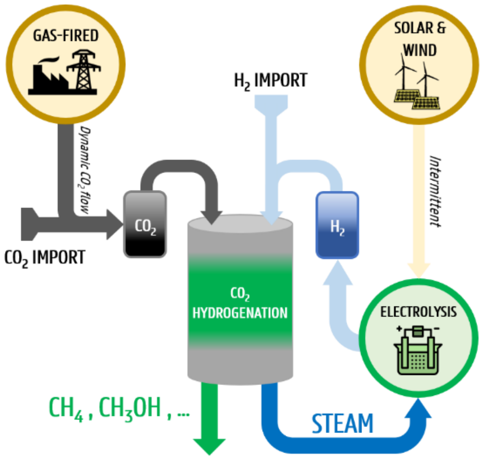

Figure 1: Schematic overview of a dynamic CCU-electrolyser system.

Program

1. Literature review: alkaline/PEM/solid oxide electrolysis, methanation/methanol reactors, system models.
2. Develop dynamic process models in MatLab: electrolysis, CO_2 hydrogenation, separation, buffering systems.
3. Investigate the influence of various system parameters: reactor/column dimensions, buffer tank size, installed electrolyser capacity, etc.
4. Optimize the plant performance for different power curves to study the impact of the power curve.