Flexibility effects in the synthetic natural gas production from biomass gasification coupled with carbon capture

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Highlights

- Syngas from biomass gasification must be processed by carbon capture or carbon utilization.
- Combination of carbon capture and utilization is the most cost-efficient process.
- This work shows how the integration of the two processes can lead to an optimal solution.

1. Introduction

The introduction of power-to-gas processes combined with CO_2 point sources suffers from the requirement of large amount of H_2. Even though H_2 can be produced from cheap electricity on short periods, the economic performance of a power-to-gas plant operating for the full year is low. For this reason, it would be useful to define the possibility of operating a power-to-gas plant in a flexible mode, utilizing H_2 only at the times when this is available at low cost. In this work, we analyze the possibility of coupling carbon capture by amines and carbon utilization by methanation downstream of a biomass gasification plant. We analyzed the requirements in terms of carbon capture and methanation for the standard production of SNG from biomass gasification and defined the economic performance of this benchmark process. We defined the requirements in terms of renewable energy needed to completely convert the available biogenic CO_2 into SNG. At last, we defined the possibility to flexibly combine these two processes to maximize the profitability of the system, taking advantage of the multiple operation mode.

2. Methods

The process analyzed include a fluidized bed biomass gasification unit, which produces a syngas composed of CO, CO_2, H_2 and a few pt. % of CH_4. Syngas needs to be cleaned from the contaminants (tars, sulfur etc.) to be further processed. These gas cleaning units are included in the process optimization. In the standard configuration, CO is converted in a water-gas-shift unit, to produce a mixture of CO_2 and H_2. The excess CO_2 for the methanation reaction is removed in an amine scrubber, which is operated with waste heat from the other process units. The resulting stream is converted to SNG. In the flexible process configuration, the methanation unit is sized to be able to convert the entire CO_2 stream by addition of further renewable H_2. In this way, CO_2 is removed when electricity cost is high or converted when this latter cost is low. The process simulations are performed in Aspen Plus based on rate-based models [1,2], based on experimental results recorded in industrial-scale plants [3,4]. The conceptual scheme of the processes simulated is shown in figure 1.

3. Results and discussion

The full CCU process configuration is unsustainable in the current market conditions. The system needs excessive amount of H_2, which is available at too high cost for approximately 2000 h/y. Additionally, the surface of PV required to fully convert CO_2 is too large. The optimal operation time for the system in CCU mode is calculated in approximately 6000 h/y. In these conditions, the system can fully take advantage of renewable energy production compensating the additional CAPEX originated by the flexible solution. In the current conditions, the process configuration with only CCS remains the most convenient, because of the cost of electrolysis. It is however foreseeable that the decrease of electrolysis cost in the future, combined with the cost required for CO_2 handling, will make the flexible solution a cost competitive option. Figure 2 shows a typical result of the simulations, showing how the flexibilization of the process allows increasing the profitability of the system, by following the electricity price and adapting the energy demand of the plant.

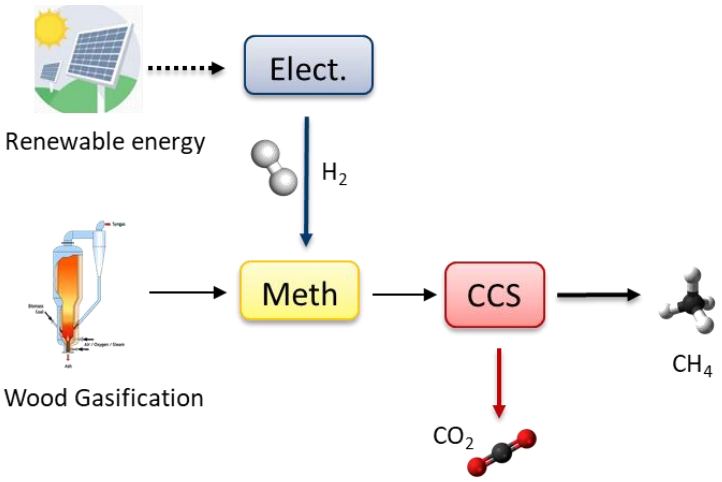

Figure 1. the conceptual process of the flexible CCS/CCU principle from wood gasification

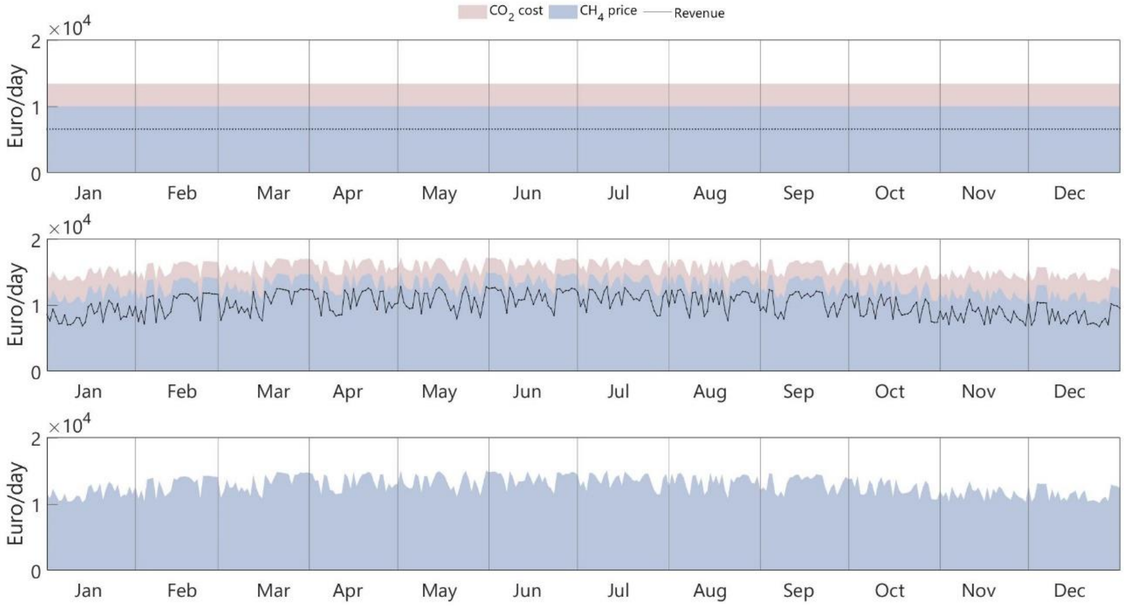

Figure 2. the structure of the results for the steady state and flexible methanation processes

4. Conclusions

This works shows how dynamic optimization is essential to unlock the potential of renewable energy processes and sector coupling. We will show how to optimize a complex process in a dynamic context. Furthermore, this work paves the way for the integration of CCS and CCU strategies to minimize the cost of avoiding CO_2 emissions, while optimizing the produced energy vectors.

References

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Keywords
Biomass gasification, methanation, flexible processes, dynamic optimization