Carbon dioxide removal via bio-hydrogen production from non-traditional bioresources

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The struggle to achieve CO_2 emissions reductions according to the mitigation targets is dramatically increasing the importance of developing carbon dioxide removal (CDR) solutions. Among the available options for CDR, carbon capture and storage from processes using biomass (BioCCS) exhibits a unique combination of characteristics: large potentials, relatively low costs, permanent sequestration of CO_2, and the possibility to obtain useful products.

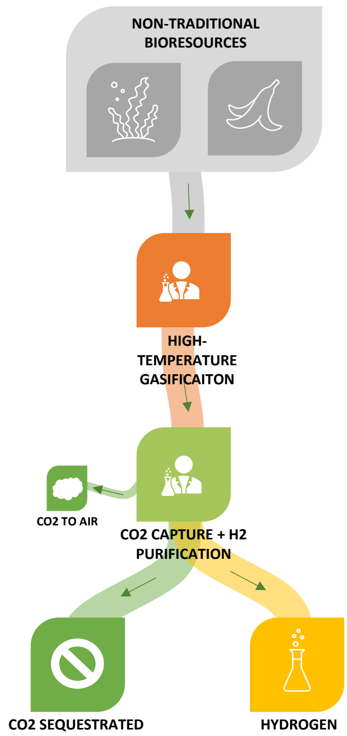

Figure 1. Simplified scheme of a bioresources-to-hydrogen process.

Everson et al. [1] have recently shown the importance and potential of "non-traditional bioresources" in the Norwegian context. The umbrella term "non-traditional bioresources" includes challenging bioresources that are commonly seen as byproducts (e.g., residues from forestry management), wastes (e.g., municipal solid waste) or that display peculiar characteristics (e.g., algae which have a high moisture and salt content). In countries where heat and power demands are met with renewable sources, the bioresource is likely to be used for hydrogen production. This study thus seeks to develop and evaluate the BioCCS pathway to CDR via the conversion of non-traditional bioresources to deliver hydrogen integrated with CCS (Figure 1).

To develop an effective solution, we analyse the key elements of the bioresources-to-hydrogen process by means of modelling and simulation.

First, we will assess the optimal bio-feedstocks conversion considering the challenges posed by the utilization of non-traditional bioresources, such as heterogeneous composition or high levels of moisture and impurities (e.g. ash-forming elements). High-temperature gasification is the technological solution considered for this study. Depending on the syngas conditions obtained and the characteristics of the bio-feedstocks used, syngas cleaning and upgrading processes will also be modelled and simulated. Figure 2 shows preliminary results on the effect of equivalence ratio and temperature on CO_2 formation during the gasification of a representative bio-feedstock. The syngas composition was simulated using a non-stoichiometric equilibrium model [2]. The model's results are validated against experimental results (while a single data point is reported in the figure more experimental results will be available for benchmarking). High concentrations of CO_2 are targeted to ease the downstream CO_2 capture process.

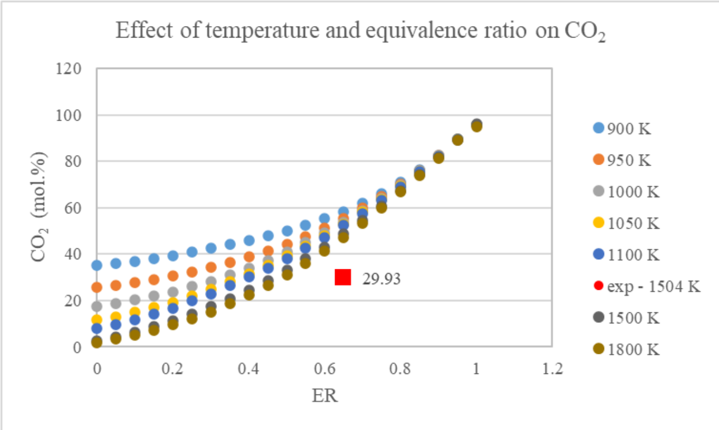

Figure 2. Effect of temperature and equivalence ratio on CO_2 molar fraction in the synthesis gas.

Second, we will investigate the suitable technologies for the downstream gas separation tasks, i.e., CO_2 capture and H_2 purification. The analysis goes beyond the state-of-the-art by considering process configurations and possibly hybrid solutions leading to process intensification and integration opportunities. Well-designed combinations of adsorption and low-temperature separation proved to be attractive options (Figure 3).

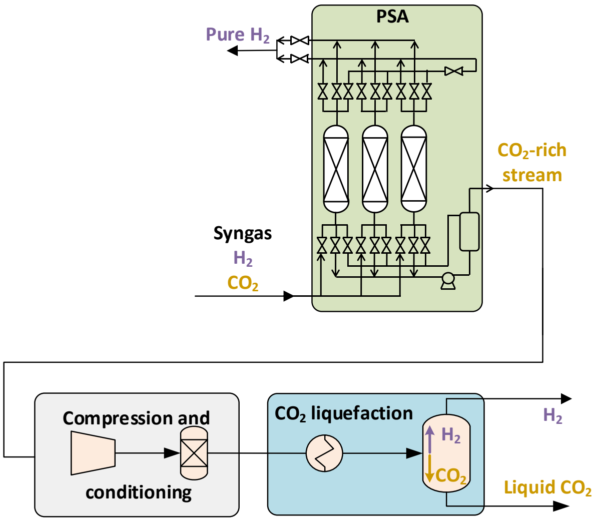

Figure 3. Process flowsheet of a pressure swing adsorption (PSA) - CO2 liquefaction hybrid configuration.

Finally, the ideal integration between the conversion and the gas separation technologies will be studied. A system optimization framework is developed. This optimization strategy allows to inherently explore the mutual influences between the various process units and, if successfully implemented, to seek for the system optimum. The ultimate objective is to design a process that delivers negative emissions at maximum efficiency.

Acknowledgement

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References

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