Hydrothermal liquefaction and aqueous phase reforming coupling for the production of biofuels: a life cycle assessment.

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Introduction

Hydrothermal liquefaction (HTL) is a thermochemical process which can be used to treat different matrixes and valorise them into an organic phase (biocrude). Next to the desired product, the HTL produces also a carbon-laden aqueous stream (Panisko et al., 2015). The hydrogenation of biocrude is pivotal to produce a commercial biofuel. However, the dependence from hydrogen of the process led to the necessity to find greener hydrogen production systems. Aqueous phase reforming (APR) can be a viable option. The APR is a reforming process in liquid phase, which can convert oxygenated hydrocarbons into a gas rich in hydrogen at mild temperature and pressure (200-270°C, 25-60 bar) (Cortright et al., 2002). Moreover, the APR can also reduce the organic content of the water reducing the need of waste disposal and increasing the carbon efficiency of the whole process. HTL exists in pilot plant scale (Castello et al., 2018) and APR for hydrogen production is only at laboratory scale, for this reason we performed a life cycle assessment (LCA) of the HTL-APR combined plant. This is a necessary tool to understand the feasibility of the commercial development. Few LCAs can be found in literature regarding HTL and APR. In this work, to the best of our knowledge, the LCA of the combination of HTL and APR is presented for the first time. Two cases using different biomass residues were studied: corn stover (CS) and lignin rich stream (L).

Method

The material and energy balance, together with the design of the main equipment, were previously performed in a separate work, using data derived from a laboratory-scale experimental campaign [under submission]. The environmental analysis of the HTL APR combined plant was carried out with LCA methodology (ISO 14040 and ISO 14044) (European Commission-Joint Research Center, 2010). The software GABI was used, and the impacts were evaluated by ILCD v1.09 method according to three categories (Global warning potential (GWP), Terrestrial Eutrophication (TE) and acidification (AC)).

Results

The goal and scope of this work is to assess the environmental impact of the combined HTL+APR plant and compare the difference between the lignin and corn stover cases. The system boundary is from feedstock arrival to biofuel production; the functional unit is 1 kg of biofuel, since the HTL is the defined product. No allocation is needed, and the plant is based in Europe. The complete inventory list is based on the conceptual design of the HTL-APR plant reported in a previous work of the same research group. Thanks to that, the inventory list step, often the most consuming of the LCA, is complete and robust leading to a reliable impact assessment. In Figure 1 the main sections included in the system boundaries are reported, with the defined product highlighted in green.

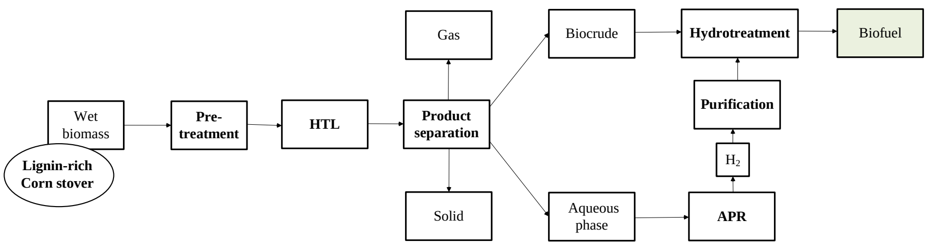

Figure 1: block flow diagram of HTL-APR plant.

Finally, the GABI model of CS plant is showed in Figure 2 (above) and, for brevity, only GWP category is reported in Figure 2 (below). In the GABI model the percentages on the impact of the single blocks are highlighted. Since the feedstocks are biomass residues the impact of their CO_2 emission can be reduced considering it as biogenic carbon. Looking at GWP results the heating and the electricity have the biggest influence. Different sources of energy are evaluated to improve the sustainability. The impact related to HTL and APR are referred to gas (alkanes) produced by the reactions themselves; to reduce their impact they should be sent to a torch and converted into CO_2

before releasing them in the air (alkanes have higher GWP impact compared to carbon dioxide). Comparing the GWP impact between CS and L is clear that the higher production of solid char, from lignin HTL, led to a higher impact on the furnace but a lower demand of external heat, which is necessary in the CS case.

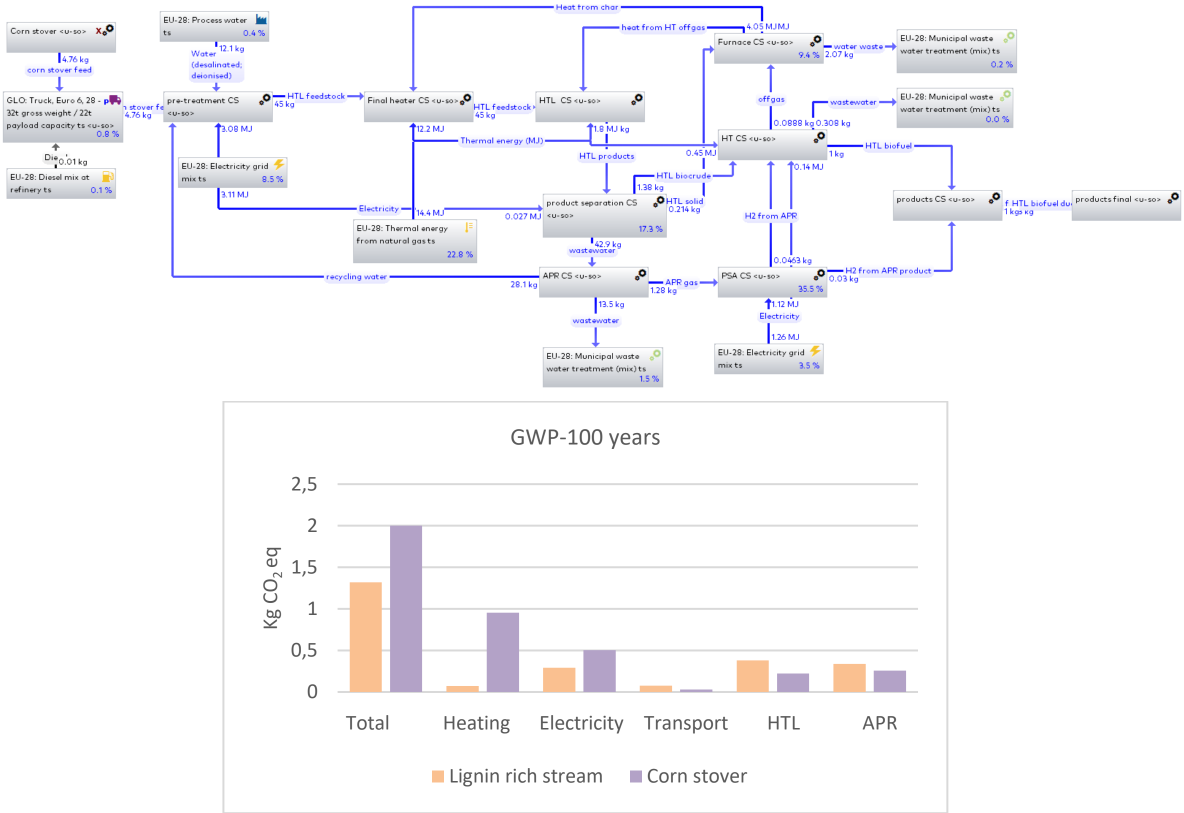

Figure 2: GABI model (above) and GWP results (below).

The comparison with other works, fast pyrolysis biofuel (Peters et al., 2015), bioethanol (from fermentation), bio-oil from pyrolysis and jet fuel from gasification of corn stover (Sun et al., 2021) has been performed. However, these works have different boundaries condition and functional unit. To simplify the comparison their functional unit (MJ of biofuel) was used assuming the produced biocrude as diesel (LHV = 43 MJ/Kg). The CO_2eq/MJ of biofuel from the HTL-APR plant was comparable with fast pyrolysis biofuel and biooil form corn stover pyrolysis.

Conclusion

HTL-APR combined plant may be a valuable option to obtain a biofuel starting from biomass residues. The GWP impact of the production was evaluated, and it was found that is comparable with other biofuels systems and lower than fossil fuel diesel. The LCA together with techno-economic assessment are pivotal steps for the industrial implementation of these innovative technologies, which could help to decarbonize the transport sector.

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