WASTE TO HYDROGEN WITH CCS: LIFE CYCLE ASSESSMENT OF PLANT OPERATION AND FEEDSTOCK VARIATION

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1. Introduction

This research work focuses on a complex product system that a) utilises different waste feedstock, thereby diverting its fate from landfill or incineration b) produces hydrogen as the main product (for heating and transport applications) c) captures and permanently sequesters carbon dioxide, a by-product. The multi-functionality of such a system lends itself to complexities arising from the choice of system boundaries, functional unit, and assumptions in order to integrate mature, commercial scale elements of the process with other sections at a lower technology readiness level. A novel waste technology and their integration into connected systems is presented and includes transport of waste from source and its pre-treatment, hydrogen for heating or transport and captured carbon dioxide for permanent sequestration.

Recently, hydrogen from low-carbon routes has garnered attention as a high-density energy vector with low greenhouse-gas production emissions and no emissions at its point of use. The UK Hydrogen strategy sets forth a target of 5GW of low carbon hydrogen production capacity by 2030 (BEIS, 2021). A proposed low-carbon route to produce hydrogen is the gasification of waste feedstock coupled with pre-combustion capture and long-term geological storage of carbon dioxide. This research also analyses the effect of waste feedstock composition on the environmental impact of the process. The three feedstocks analysed are waste wood, municipal solid waste (MSW) and mixed plastic waste (MPW).

2. Materials and methods

2.1. Process Modelling

A fully integrated biohydrogen system was developed and the performance and balance of the plant was predicted using Aspen Plus simulation software. Models were validated using a combination of extensive operating experience, data from a commercial scale Bio-SNG plant located in Swindon, UK (with relation to syngas generation, cleaning and CCS sections), literature data for hydrogen purification packages. The hydrogen produced is to a high purity of that required for use in fuel cells and pressurised to 200 bar. CO2 is compressed to 120 bar for transport and injection (includes recompression).

2.2. Life Cycle Assessment

Following the guidelines of the ISO 14040 and ISO 14044 standards the LCA methodology was applied (ISO, 2006a, 2006b). The goal of this study was to investigate the environmental and carbon performance of converting waste wood, MSW and MPW to hydrogen, while also capturing CO2 process emissions. The system boundary begins with the transport of waste to the thermochemical treatment plant. This is assumed to be 50 km transported via lorry. The processing stages include syngas generation, syngas cleaning and conditioning, carbon capture, hydrogen purification and compression. The CO_2 captured is transported via lorry, sea tankers and finally through pipelines prior to being injected in saline aquifier. The construction of the plant is also considered. The functional unit from both the waste perspective and the product perspective is chosen; 1 tonne of waste treated and 1 MW

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of H_2 produced respectively. The process is also compared to other current disposals method in the UK, i.e. incineration.

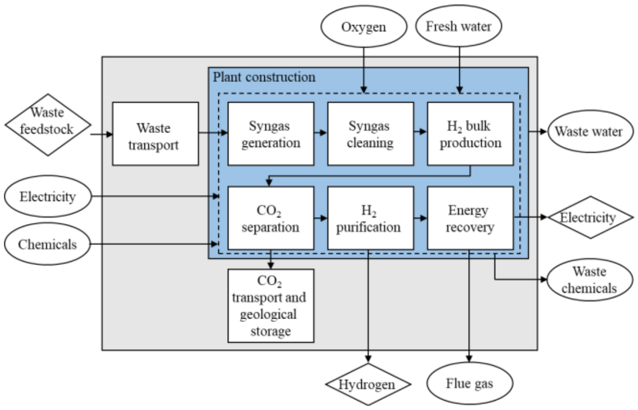

Figure 1: System boundary of studied system

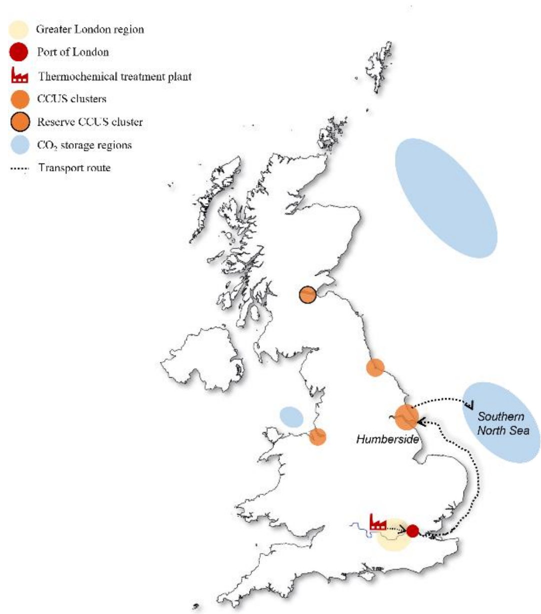

Figure 2: Map of the United Kingdom detailing CCUS infrastructure (adapted from (BEIS, 2020))

3. Results

A hotspot analysis of the process reveals largest climate change burdens during the gasification (syngas generation) and the carbon capture stages due to high thermal and electricity consumption. Although pre-treatment of waste is overall a minimal climate change contributor of the process, variations in feedstock composition and flowrates result in large relative differences as MPW benefits from a high calorific content and requires significantly lower feedstock for equivalent hydrogen production. The sequestration of biogenic CO2 from the natural carbon cycle uniquely results in negative carbon dioxide emissions. Thus, distinguishing between sequestration of biogenic and fossil carbon is the most significant differentiator in how these technologies fare environmentally. Using waste wood and MSW feedstock result in negative emission processes, while MPW does not advantage from biogenic carbon sequestration. Despite this, results when considering counterfactual scenarios, namely incineration and landfill, reveal the avoided burdens of MPW treatment.

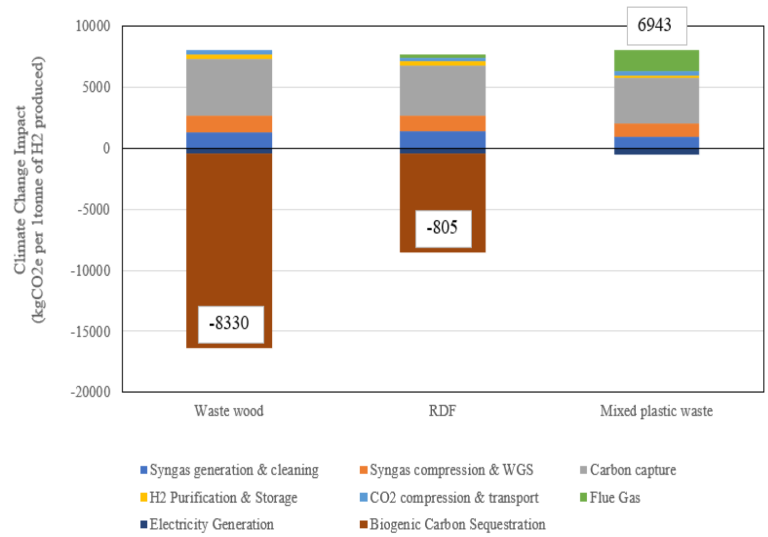

Figure 3: Climate change impact results for main processing stages (Functional unit: 1 tonne of hydrogen produced)

4. Conclusion

Advanced gasification with CCS is proposed as a potential end-of-life management. In light of net-zero targets, the production of H2, with technological flexibility in desired purity, is a crucial feature of the process. The treatment of production of Hydrogen (with CCS) is proposed as a suitable technology for treatment of MSW with varying compositions.

5. References

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