ADVANCED THERMOCHEMICAL CONVERSION OF VARIOUS WASTE FEEDSTOCKS WITH CCS FOR CLEAN HYDROGEN PRODUCTION – A LIFE CYCLE ASSESSMENT

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This research work focuses on a complex product system that c) 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. This research focuses on novel waste technology and their integration into connected systems, specifically transport of waste from source and its pre-treatment, hydrogen for heating 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 [1]. 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 feedstock analysed are waste wood, municipal solid waste (MSW) and mixed plastic waste (MPW).

The facility is designed and modelled to convert approximately 110,000 tonnes per annum of chosen waste to approximately 50 MWh of grid-quality hydrogen. Carbon dioxide is captured using a Benfield CO_2 stripper technology. Following the guidelines of the ISO 14040 and ISO 14044 standards the LCA methodology was applied. 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 CO_2 process emissions. The comprehensive LCA also includes the integration into connected systems, namely the transport of waste, pipeline transport and sequestration of CO_2. All impact categories were considered according to the EF 3.0 method.

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 CO_2 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. Nonetheless, gasification technology applied to the treatment of waste to produce hydrogen with CCS is proposed as a suitable technology for treatment of varied waste feedstock.

[1] Business, Energy & Industrial Strategy. 2021. UK Hydrogen Strategy. ISBN 978-1-5286-2670-5