Environmental Performance of Hydrogen Production from Industrial Waste: Towards Circular Economy

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One of the most practical options for decarbonization is using hydrogen as an alternative energy carrier. Given that it emits no pollutants, hydrogen has a lot of potential for use in transportation, whether as a fuel for fuel cell electric vehicles (FCEVs) or as a feedstock for synthetic fuels (Mohideen *et al*, 2023; Ampah *et al*, 2022; Mohan & Pandey, 2013). According to Rau *et al* (2018), hydrogen, which is regarded as the ideal energy source, will play a significant role in future energy systems. Upgrading the hydrogen economy is essential in light of the current environmental situation brought on by the negative consequences of climate change. Therefore, performing hydrogen sulphide gas (H_2S) splitting to produce hydrogen from a waste product such as H_2S aligns with the goals of the hydrogen and circular economy. In this paper, a cradle-to-gate Life cycle assessment (LCA) was conducted on a microkinetic multistep reaction model that was developed and simulated using CHEMKIN® software to replicate a pilot-scale plant by integrating the two-step solar thermochemical H_2S decomposition. The proposed LCA methodology for the two-step solar thermochemical H_2S decomposition using the microkinetic multicriteria reaction model comprises of goal and scope definition, life cycle inventory, life cycle impact assessment, and interpretation as standardised in ISO standards14040 (2006) and 14044 (2006). The H_2S decomposition in this study consists of cyclic sulfurization and regeneration phases which requires high temperature to conduct the process as shown in equations (1) and (2). The functional unit used in this study is '1 kg of H_2 per day' to assess the environmental performance of the operational phase of the simulation plant. The stages involved in the cradle-to-gate system boundary are demonstrated in Figure 1.

$$H_2S\,(g) + Ni_3S_2 \rightarrow 3NiS + H_2\,(g) \quad (1)$$

$$3NiS + Heat \rightarrow Ni_3S_2 + S\,(g) \quad (2)$$

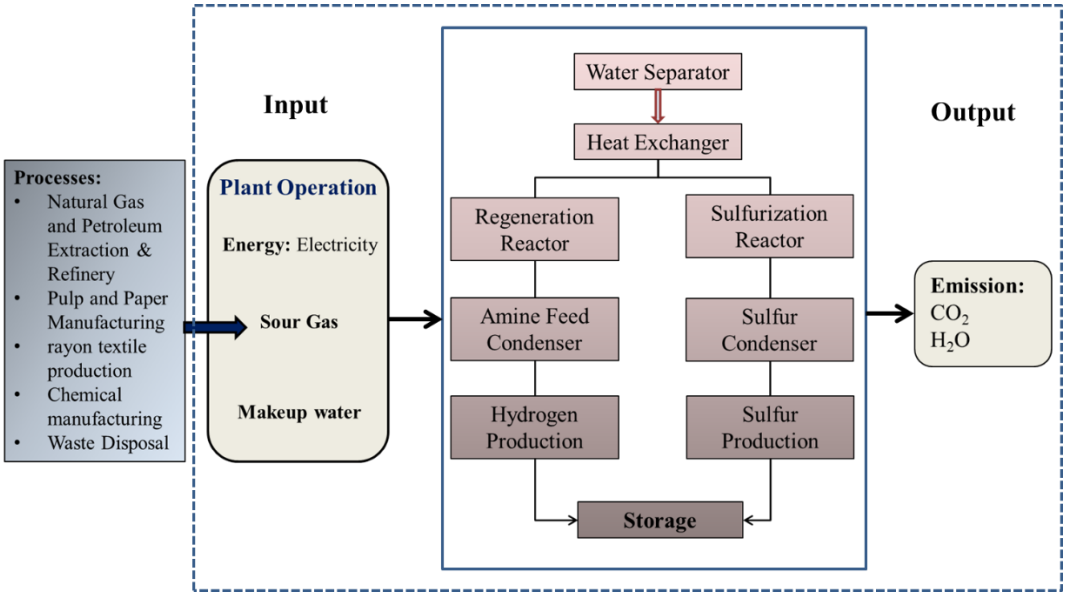

Figure 1: System boundary of the microkinetic multistep reaction model

Among all the three midpoints assessed, sour gas has the highest relative contribution towards global warming potential (GWP) and terrestrial ecotoxicity potential (TETP) with a percentage of 98.03% and 73.46%. Whereas land use potential (LUP) is highly contributed by electricity (94.43%). Sour gas has a higher impact towards GWP and TETP as it is a waste product from industrial sectors with contains toxic gases. Electricity

powered by renewable resources such as solar requires a large space of land to install the solar panels and therefore it explains the high contribution towards LUP. Sour gas has the highest impact on the aspects of human health, ecosystems, and resources among the other inputs. Scenario analysis was assessed by setting the solar-powered electricity as the baseline and was compared with electricity from different sources such as wind and nuclear for the H_2S splitting plant. Based on the sensitivity analysis conducted, it can be concluded that electricity powered by renewable sources preferably solar power significantly reduces the environmental burden compared to wind and nuclear sources. Hydrogen, as a versatile molecule that affects many industries, has the potential to significantly reduce these emissions by utilising renewable energy sources (Ourya & Abderafi, 2023). However, several policy implications such as investing in renewable energy infrastructure, providing financial incentives, introducing a carbon tax, promoting a carbon tax, and creating energy storage technologies have been suggested in this paper that are beneficial in promoting hydrogen as an energy carrier.

Keywords: Hydrogen sulfide, life cycle assessment, environmental performance

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