Assessing the environmental implications of manure waste management and its application in purple hydrogen production

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Introduction

Global greenhouse gas (GHG) emissions have been on rise from previous decades and the increasing population is one of the leading reasons of these emissions. Increasing population is putting a strain on energy and agriculture sector due to the increase in demand (Maja & Ayano, 2021). This makes energy sector the highest and agricultural sector the second highest contributor to GHG emissions (Hannah Ritchie,2020). To counter this, more than 160 countries in COP-28 pledged to discard the use of fossil fuels and adopt green sources (Jiang et al., 2024). In recent years hydrogen has risen as a promising alternative to conventional fuels. Hydrogen production routes are divided into colour spectrum based on the technical aspects of the production technique. Currently 95% of hydrogen is produced by fossil fuels out of which 75% comes from steam methane reforming (SMR) termed as grey hydrogen. Green hydrogen produced by the electrolysis of water using wind energy is considered as a green alternate, however, it contributes only 1% to the global hydrogen production (Kourougianni et al., 2024). Meanwhile, the increased pressure on agricultural sector results in higher amount of bio-waste produced which is responsible for 70% of the agricultural GHG emissions. Manure waste is largely employed as fertilizer for crops; however, intense farming is leading to surplus amount of manure which needs to be consumed in another application (Köninger et al., 2021). Energy production through biomass is in trend and employing farm biowaste to produce energy can be a feasible option to reduce the environmental implications of biomass produced. This biomass can also be used to produced hydrogen termed as turquoise hydrogen (Diab et al., 2022). It employs pyrolysis process to break the chemical bond in methane leading to production of hydrogen and solid carbon. Turquoise hydrogen shares less than 1% of total production share, however, there is a potential in increasing the production specially for countries having high agricultural yield and livestock. Despite employing biowaste there is a need to assess whether the turquoise hydrogen is environmentally sustainable as compared to the conventional hydrogen production techniques. Therefore, this study will assess Spanish farms bio-waste for turquoise hydrogen production.

Methodology

Life cycle assessment (LCA) is employed to assess the environmental implications of turquoise hydrogen production. ISO 14040-14044 framework is followed to carry out a comprehensive LCA study. A comprehensive LCA study is comprised of four steps namely: goal and scope definition, life cycle inventory (LCI), life cycle impact assessment (LCIA) and interpretation (ISO 14040,2006). The goal of the study is to assess the global warming potential (GWP) impact of hydrogen production through biomass produced via livestock. Spain is assumed as the geographical location in this study and the functional unit (FU) is 1 kg of hydrogen produced. The boundary conditions of the study are shown in figure 1. Inventory for hydrogen production is gathered from secondary sources whereas the inventory for farms and manure production is acquired through primary farms based in Spain. For LCIA, IPCC 2021 GWP 100 will be used to assess the GWP impacts. In the interpretation step, purple hydrogen CC impacts will be compared with grey hydrogen, green hydrogen and blue hydrogen to compare the environmental implications of mainstream hydrogen production routes.

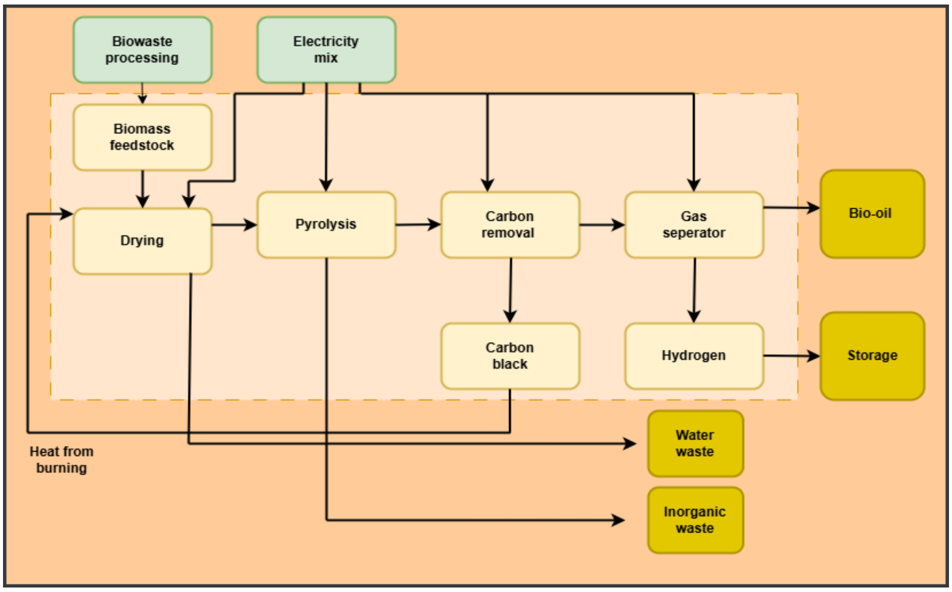

Figure 1: Boundary condition diagram for hydrogen production from biowaste

Preliminary results

Grey, blue and green hydrogen are modelled in LCA whereas the turquoise hydrogen is still being modelled. The preliminary results showed that grey hydrogen shows the highest GWP of 12.06 kg CO_2-eq. per FU. CO_2 production as the byproduct in SMR is the hotspot in grey hydrogen. When carbon capture system (CCS) is modelled it decrease the emissions by 64% valued at 4.34 kg CO_2-eq per FU. In comparison green hydrogen shows total emissions of 0.64 kg CO_2-eq per FU. Highest scope 1 emissions are observed in grey hydrogen whereas no emissions were observed for green hydrogen. In literature per kg of turquoise hydrogen produced results in between 1.16-6.4 kg CO_2 eq. depending on the energy source used for the process. Also, pyrolysis reactor differ which can impact the overall electricity consumption. Turquoise hydrogen at 100% efficiency produce no scope 1 emissions however solid carbon waste is produced in the process. Also producing turquoise hydrogen at the farm can result in significant decrease in scope 3 emissions as no transport and secondary storage will be required. These assumptions will set the base for the LCA modelling of turquoise hydrogen. A comparison of GWP of already modelled hydrogen routes with literature results of turquoise hydrogen has been shown in figure 2.

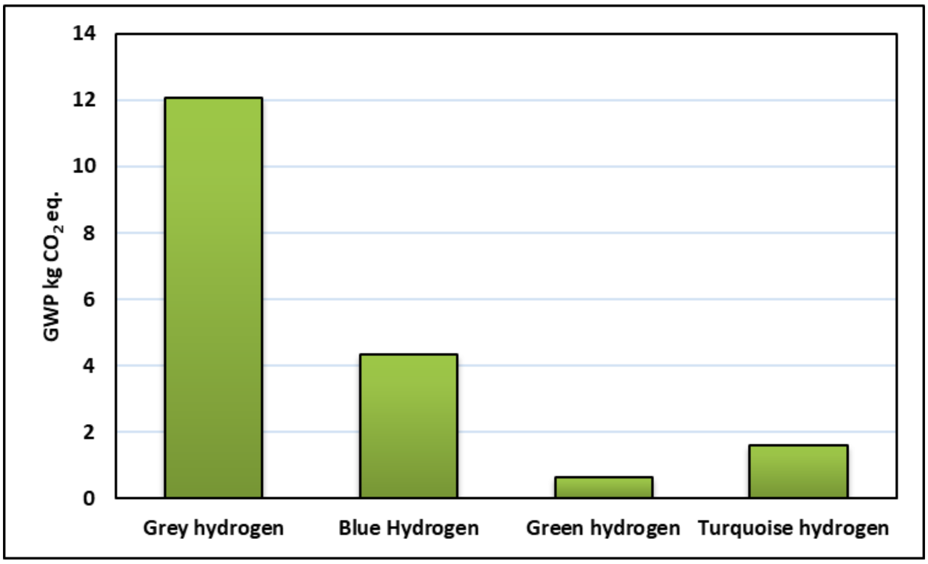

Figure 2: GWP of different hydrogen production routes

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