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How 'green' is my hydrogen? A comparative study of land, water, and wastewater footprints of renewable hydrogen production

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Abstract: Hydrogen produced by the electrolysis of water using renewable electricity is referred to as 'green hydrogen' due to its zero-emission nature. The energy used for electrolysis is generated from renewable sources such as solar and wind. The production of green hydrogen will therefore require considerable land and water resources. Land is necessary for renewable energy generation. High purity water is required for electrolytic conversion to hydrogen and oxygen gas. Given water resources (e.g., seawater, groundwater, surface water) vary in quality, treatment is needed which increases the raw water demand and produces a wastewater stream.

Global economies are aiming to reach net-zero emissions by 2050. Green hydrogen is anticipated to play a significant role in achieving this by decarbonising sectors, such as industry and transport, which are not easily met by electrification. Australia's ambition to lead this transition requires the rapid development of large-scale hydrogen production and will therefore require a continuous demand for high-quality water in the near term and into the future. Impact assessments underpinned by reliable data are critical to the sustainability of the hydrogen industry and the prevention of environmental harm. For this, quantitative estimates of the land and water footprints of green hydrogen developments need to be well understood. The green hydrogen industry is emerging in Australia and there is limited guidance or consistency in reporting of land, water, and wastewater footprints.

Our study aims to: (1) compile a database of the existing land and water requirements relevant to green hydrogen footprints; and (2) develop consistent frameworks for reporting on land and water footprints of green hydrogen developments in environmental impact assessments.

The database was compiled using publicly available information relevant to land, water, wastewater, and energy for 35 renewable energy (solar and wind) and 28 hydrogen production developments, as well as wider literature. Data from the proposals was used to estimate the land footprint (ha/MW electricity) of renewable energy generation and water footprint (L/kg H_2) of green hydrogen production. The reporting frameworks were developed based on an understanding of the industrial processes required for these developments.

Estimates of the land footprints were similar across proposals for solar developments (~2.4 ha/MW, $R^2 = 0.88$); however, the footprints of wind developments were not (~0.33 ha/MW, $R^2 = 0.11$). Additionally, analysis of satellite imagery found a high correlation between reported (predicted) and observed (actual) footprints for solar development, although the footprints for wind developments were over-reported. Estimates of the water (8.7 to 239.5 L per kg hydrogen) and wastewater (2.2 to 174.4 L per kg hydrogen) footprints were not consistent across hydrogen production developments due to a combination of inconsistencies in reporting and factors such as source water types and cooling loads.

The inconsistency in the estimated footprints highlights the need for consistent frameworks of reporting to provide reliable quantitative land and water footprints of green hydrogen which are required for strategic planning and environmental impact assessments. The frameworks developed in the study, if used consistently in reporting, can allow for better assessments of the potential impacts and hazards associated with green hydrogen development. The information included in this study it intended to aid in policy development for the rapid transition towards a net-zero economy and identifying suitable locations for large-scale, sustainable hydrogen production.

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