Geothermal-Driven Green Hydrogen Production as a Pathway to Renewable and Low-Carbon Energy Systems: Evidence from the Kamojang Integrated Multi-Energy Hub, Indonesia

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Abstract. Green hydrogen produced via water electrolysis from renewable electricity is widely identified as a critical decarbonisation vector for hard-to-abate sectors, yet geothermal energy remains underexamined as an electrolysis power source relative to solar and wind. This paper investigates whether geothermal-backed hydrogen production offers structural advantages over variable renewable alternatives and under what conditions the model can scale from pilot to commercial viability. The study draws on the Kamojang Geothermal Hydrogen Plant (GHP) in Bandung Regency, West Java, Indonesia, commissioned in February 2024 and currently the first integrated geothermal-to-hydrogen facility in Southeast Asia. Data are sourced from operational disclosures by PT PLN Energi Primer and PT Pertamina Geothermal Energy, supplemented by published techno-economic assessments, life-cycle emission estimates, and IRENA and IEA benchmark datasets. The analysis evaluates system configuration, resource efficiency, and carbon intensity against comparable solar- and wind-powered hydrogen projects. Findings indicate that geothermal baseload power, operating at 90 to 95 percent capacity factor, reduces the levelised cost contribution of electrolyser capital by an estimated 40 to 50 percent relative to solar PV based systems. Reuse of geothermal condensate as electrolysis feedstock further improves system efficiency and eliminates freshwater demand, while life-cycle carbon intensity falls below 1 kg CO2 per kilogram of hydrogen. Five structural barriers constrain scaling: electrolyser capital costs, an embryonic distribution network, reservoir water balance management, the absence of domestic carbon pricing, and unproven p-SOEC membrane durability under geothermal steam chemistry. These findings suggest that geothermal-driven hydrogen is technically competitive for resource-rich developing nations, but commercial viability depends on targeted governance instruments, particularly green hydrogen certification, carbon pricing, and anchor industrial offtake agreements, rather than further technical demonstration alone.

Keywords: *green hydrogen; geothermal energy; low-carbon energy systems; decarbonisation; multi-energy hub; energy transition.*