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Analyzing the impact of the potential use of electrolyzer waste heat on the German energy transition

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Germany's updated National Hydrogen Strategy aims to establish a strong hydrogen economy with 30 GW of electrolyzer capacity by 2030 and a comprehensive hydrogen transmission network [1]. This is crucial for energy storage, industrial decarbonization, and reducing energy import dependence—an increasingly important goal since Russia's invasion of Ukraine. However, renewable hydrogen production is energy-inefficient, losing over 20% of input energy as heat during electrolysis [2]. This waste heat has been largely overlooked but could significantly enhance efficiency if repurposed for heating. This paper analyzes the potential role of electrolyzer waste heat utilization on Germany's energy transition, focusing on its implications for electrolyzer placement and heating infrastructure.

This analysis employs the Global Energy System Model (GENeSYS-MOD), developed by Löffler et al. [3] based on the Open Source Energy Modelling System (OSeMOSYS). GENeSYS-MOD is a linear techno-economic optimization model, that aims to minimize system costs while accounting for long-term emission reduction pathways. Energy demands are provided exogenously for the electricity, buildings, industry, and transportation sectors. The model incorporates sector coupling, a wide range of technologies, and trade mechanisms to meet these demands effectively. Results are computed with hourly precision.

GENeSYS-MOD is applied to Germany, segmented into 18 regions (16 federal states and two offshore zones), with results calculated in five-year intervals from 2025 to 2050. The analysis incorporates key energy transition policies, such as expansion targets for wind, solar, and electrolyzer capacity as well as the phase-out of coal and nuclear power.
Electrolyzer waste heat is modeled as a secondary output of the electrolyzer technologies alongside hydrogen and can be converted into district heating for both industrial and residential use. Two scenarios are compared in order to analyze the effect of the utilization of waste heat: one incorporating electrolyzer waste heat utilization and one excluding it. Additionally, a comprehensive sensitivity analysis on the costs associated with waste heat recovery and transport is conducted.

The findings indicate that electrolyzer waste heat could supply nearly 30 TWh (6%) of Germany's low-temperature heat demand by 2040, with a particularly notable contribution in northern Germany, where in some states it could meet over 50% of district heating needs. By 2030, approximately 55% of the heat generated by electrolyzers is expected to be recovered, increasing to more than 90% in subsequent years. However, the overall composition of the heating sector remains largely unchanged.

Integration of electrolyzer waste heat utilization leads to a near-complete shift away from offshore hydrogen production, with Lower Saxony emerging as a key beneficiary. While hydrogen production remains concentrated in northern Germany, some southern states experience an earlier scale-up.
Utilizing waste heat improves energy efficiency, resulting in increased full-load hours for electrolyzers and boosting domestic hydrogen production. This reduces Germany's dependency on hydrogen imports, enhancing energy security. The Sensitivity analysis demonstrates that waste heat recovery remains economically viable even under substantially higher cost assumptions.
The use of electrolyzer waste heat provides significant support for Germany's heat supply and hydrogen economy. Its cost-effectiveness could make it a critical factor in future electrolyzer site selection and a meaningful contributor to the energy transition.

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