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Designing Efficient Hydrogen Subsidies for Europe's Hard-to-Abate Sectors: A Coupled Energy-System and Technology Diffusion Analysis

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Extended Abstract

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Abstract Summary

Decarbonising Europe's hard to abate sectors, such as heavy industry, aviation, shipping, and long distance transport, requires policy support for low emission technologies beyond direct electrification. Hydrogen is widely regarded as a key option in these sectors, yet deployment has lagged behind targets due to high costs, investment risk, and uncertainty surrounding market formation. This raises critical questions about how hydrogen subsidies should be designed to maximise emissions reductions while minimising policy costs.

This study evaluates the effectiveness of alternative hydrogen support schemes using an integrated modelling framework that couples a sector specific technology diffusion model (HyADOPTS) with a spatially and temporally resolved European energy system model (Balmorel). The framework captures interactions between hydrogen demand, electricity markets, infrastructure deployment, learning effects, and climate policy. Four scenarios are analysed over 2022–2050: (i) an unsubsidised baseline driven by carbon pricing, (ii) a uniform hydrogen production premium, (iii) a targeted, auction based subsidy linked to sector specific cost gaps, and (iv) a mandate driven scenario reflecting existing EU regulations.

Results show that uniform production subsidies strongly increase hydrogen uptake but concentrate adoption in sectors where lower cost alternatives exist, reducing overall efficiency. A targeted, budget constrained allocation mechanism leads to lower total hydrogen volumes but reallocates hydrogen to sectors with limited decarbonisation options, resulting in higher emissions reductions per euro spent. Compared to uniform premiums, the targeted scheme reduces implicit abatement costs by approximately 15–20%. Mandate driven pathways achieve deeper decarbonisation but require higher upfront system costs.

Overall, the findings highlight that hydrogen subsidy design matters as much as subsidy scale. Sector sensitive allocation mechanisms can significantly improve the cost effectiveness of public support, while integrated energy system interactions are critical for evaluating long term hydrogen policy outcomes

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Presenting Author Biography

Theis Madsen is a PhD student at the Technical University of Denmark, department of Management, section of Energy Markets and Finance. His work deals with European Power-to-X markets, focusing on European fuel prioritisation for aviation and shipping, energy infrastructure requirements, and policies for incentivising hydrogen adoption. His previous work includes hydrogen infrastrucutre strategies, modeling continental multi-carrier energy systems, and the impact of decarbonisation policies.