Energy policy

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An adjusted strategy is needed to ground green hydrogen expectations in reality

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Scaling up green hydrogen will be difficult if future projects solely depend on expensive subsidies to overcome competitiveness barriers. Policy makers need to implement supportive policies grounded in realistic expectations, focusing on hydrogen-specific support in sectors where electrification isn't feasible, while also gradually introducing technology-neutral market mechanisms such as carbon pricing.

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The policy problem

In recent years, green hydrogen has often been heralded as the clean fuel of the future. More than 60 countries have already released hydrogen strategies and companies are continually announcing new green hydrogen projects. However, current production of green hydrogen remains minimal as the vast majority of projects have been delayed or scrapped due to rising costs, regulatory uncertainty, and limited willingness to pay. Some analysts warn of a widening disconnect between expectations and reality regarding hydrogen availability and costs, which may distract from readily available and cheaper climate mitigation options. Adding to the uncertainty, climate change mitigation scenarios show a wide spectrum of potential future hydrogen shares, ranging from negligible levels to substantial portions of the future energy system. For policymakers, it is essential to realistically assess the future availability of green hydrogen, know the associated policy costs, and be aware of remaining uncertainties in order to ensure a swift market ramp-up while hedging against the risk of fossil fuel lock-in.

The findings

We identify and quantify three gaps of global green hydrogen deployment (Fig. 1). First, looking back, we find that in 2023 only 7% of the initially announced added green hydrogen capacity was eventually operational—the past implementation gap. Second, looking ahead to 2030, we find that green hydrogen projects announced by industry increasingly exceed the requirements in 1.5 °C scenarios—the closing ambition gap. Third, enormous subsidies of US$1.3 trillion would be required to realize all announced projects by 2030, far exceeding currently announced policy support, which we term the 2030 implementation gap. Policymakers should therefore interpret the increasingly steep growth indicated by recent project announcements with caution. To safeguard climate targets, policymakers must prepare for prolonged green hydrogen scarcity, low competitiveness, and high policy costs. Relying on abundant and cheap green hydrogen for the future risks crowding out cheaper alternatives such as end-use electrification, and may endanger climate targets if hydrogen continues to fall short of expectations.

The study

In our study, we start by tracking 190 individual global green hydrogen projects announced for 2023 over a period of three years. This tracking builds on three consecutive and manually validated versions of the IEA Hydrogen Production Projects Database, each providing unique project identifiers across versions. Next, we collect data on 1.5 °C scenarios, drawing from integrated assessment models (primarily from the IPCC) as well as from institutional and corporate sources like the IEA, BloombergNEF, and the Hydrogen Council. Lastly, we estimate the subsidies that would be required to realize all global project announcements until 2030, developing a model of the required policy support per unit of green hydrogen. For each of the 14 designated end-uses for green hydrogen projects, we calculate the cost gap between the green product and its corresponding fossil competitor. This cost gap, together with the volume and timing of project announcements, determines the total required subsidies.

Messages for policy

- Green hydrogen projects have recently fallen dramatically short of expectations, calling into question the reliability of steep growth rates implied by ever-increasing future project announcements.
- Relying solely on supply-side subsidies to spur green hydrogen investments will be prohibitively expensive as a substantial competitiveness gap prevails across all end-use sectors.
- Green hydrogen support should be combined with demand-side measures such as quotas that steer scarce and expensive hydrogen into hard-to-electrify sectors. Use cases can later be expanded to other sectors if supply exceeds expectations.
- Policymakers need to support hydrogen projects, but should regularly adjust related expectations in order to avoid fossil lock-ins and implement a transition to technology-neutral market mechanisms like carbon pricing.

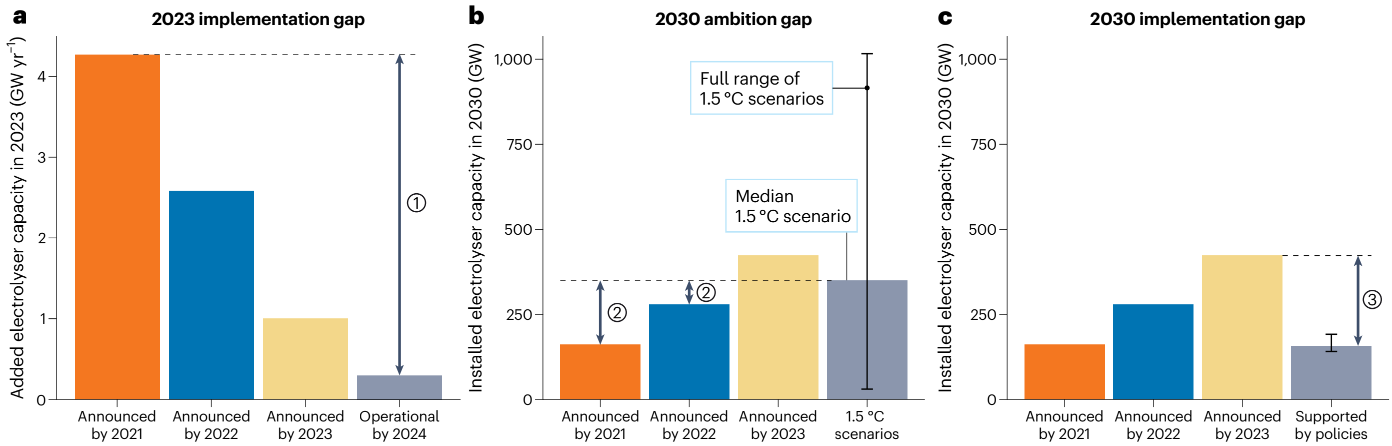

Fig. 1 | The three gaps of green hydrogen. a, The wide 2023 implementation gap, defined as the difference between initially announced green hydrogen capacity and eventually operational capacity in 2023, illustrated by arrow 1. **b**, The closing 2030 ambition gap, defined as the difference between announced green hydrogen capacity and required capacity in institutional and corporate 1.5 °C scenarios in 2030, illustrated by arrow 2. **c**, The widening 2030 implementation gap, defined as the difference between announced green hydrogen capacity and capacity that is supported by announced subsidies and demand-side policies, illustrated by arrow 3. All values are global. Figure adapted from Odenweller, A. & Ueckerdt, F. *Nat. Energy* https://doi.org/10.1038/s41560-024-01684-7 (2025) under a Creative Commons licence CC BY 4.0.

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Further reading

1. Shafiee, R. T. & Schrag, D. P. Carbon abatement costs of green hydrogen across end-use sectors. *Joule* https://doi.org/10.1016/j.joule.2024.09.003 (2024).
   This article shows that current and future prices of delivered green hydrogen translate into very high carbon abatement costs, especially if transport and distribution of hydrogen are accounted for.
2. Neuwirth, M., Fleiter, T. & Hofmann, R. Modelling the market diffusion of hydrogen-based steel and basic chemical production in Europe – A site-specific approach. *Energy Convers. Manag.* **322**, 119117 (2024).
   This article demonstrates how urgently green hydrogen is required in selected energy-intensive industries in the EU such as the production of primary steel, ammonia and carbonaceous chemicals.
3. Plötz, P. Hydrogen technology is unlikely to play a major role in sustainable road transport. *Nat. Electron.* **5**, 8–10 (2022).
   This comment article argues that the window of opportunity for hydrogen vehicles has effectively closed, and that policymakers should focus on battery electric vehicles in both passenger and freight transport.
4. Ueckerdt, F. et al. Potential and risks of hydrogen-based e-fuels in climate change mitigation. *Nat. Clim. Change* **11**, 384–393 (2021).
   This perspective article demonstrates that hydrogen-based e-fuels are likely required for very few large sectors (for example, aviation and plastics), while any expectations for road transport and low-temperature heating risk to deepen fossil lock-ins.
5. Richstein, J. C. & Neuhoff, K. Carbon contracts-for-difference: How to de-risk innovative investments for a low-carbon industry? *iScience* **25**, 104700 (2022).
   This article shows how project-based carbon contracts-for-difference can reduce investment risks arising from market and political uncertainty, using a case study from the steel sector.

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Competing interests
The authors declare no competing interests.