EUROPEAN RENEWABLE HYDROGEN REGULATION AND SUBSIDIES: ECONOMIC AND ENVIRONMENTAL IMPACTS OF DISTORTED ELECTROLYSER FLEXIBILITY INCENTIVES

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Overview

As the share of renewable power generation increases, the task of power system operators to match supply and demand necessitates mobilising new flexibility sources. Among these are electrolysers, which the EU's Hydrogen Strategy for a Climate Neutral Europe envisions as power system flexibility providers.

Such flexibility provision in coupled electricity-hydrogen systems has been modelled, with benefits ranging from easing RES integration [1], [2] to reaching energy transition targets at lower costs [3]. This literature however usually considers that electrolysis acts in a perfectly flexible way to minimise total system costs, usually encompassing operational costs or operational and investment costs of all multi-energy system technologies. Such flexible behaviours are idealistic, whereas electrolysers' primary goal is maximisation of their profit. Price signals are considered suitable incentives to make this happen concurrently to maximising social welfare, but this might not hold when several, conflicting incentives apply, e.g., in presence of regulation or subsidies.

Hydrogen regulation has been the focus of a recent literature strand, focusing on electrolysis regulation following European and American "three pillar" typologies, enforcing the criteria of additionality, temporal correlation and geographical correlation [4]. In particular, the temporal correlation criterion for EU renewable hydrogen states that in each time period, the electrolyser plant cannot consume more electricity than its portfolio of renewable power capacities generates. These studies illustrate how such regulations affect energy system costs and emissions using a central planner modelling approach, which does not account for distorted incentives of subsidised and regulated electrolysis. Conversely, recent work illustrates how subsidies impact hydrogen dispatch decisions, and consequently energy system costs and emissions [5], without considering operation constraints from EU regulation. A case study implementing both facets illustrates the potentially strong impacts of high electrolysis subsidisation even under strict temporal correlation, but produced hydrogen quantities are endogenous and not related to an identified hydrogen demand [6].

We fill these gaps by modelling the impacts of EU renewable hydrogen support and regulation on electrolyser flexibility incentives in the planned EU 2040 energy system, and the consequence this has for power system supply-demand matching.

Methods

Using the open-source multi-energy dispatch optimisation model Antares [7], we detail how electrolyser behaviour varies depending on its policy and regulatory environment, comparing implemented frameworks with alternatives, e.g., a power price-based regulation ensuring electrolysis consumption does not lead to increased thermal power generation.

We contrast optimsation results across several potential 2040 energy system scenarios. From a reference energy system scenario inspired by the 2024 Ten-Year Network Development Plan [8], we vary the development stages of the European hydrogen economy and decarbonisation of the power system (two scenarios). The model is optimised with the current EU regulation, an alternative regulation, and without regulation for comparison. Several subsidy levels – in the form of a premium on the price of hydrogen – are modelled.

Output metrics include sub-sector and total costs and emissions, renewable generation curtailment as well as more detailed flexibility metrics from existing research [9]. We observe how costs, emissions and flexibility contribution are transferred between technologies of the multi-energy model depending on the policy and regulatory environment of electrolysis.

Results

We illustrate that when electrolysers are disincentivised to interact with electricity markets due to the hourly temporal correlation requirement, RES curtailment is higher than under the alternative regulation or in the absence of regulation, and electrolysers consume power from their portfolio whereas it would have been more valuable when used for power system supply-demand matching. Emissions under hourly temporal correlation are higher than under the alternative regulation which is expected as the alternative effectively forbids grid-connected electrolyser operation when additional power consumption incurs power system emissions.

Should the deployment of European hydrogen infrastructures lag behind, lower flexibility can be provided in more local hydrogen markets by seasonal hydrogen storage or hydrogen interconnectors, which increases the flexibility needed from the power system to accommodate hydrogen demand. This makes electrolysis regulation crucial as regards energy system costs and emissions resulting from power system operation. The same conclusion holds when the 2040 power system is late on EU decarbonisation targets.

Operational subsidies incur an opportunity cost for electrolysers selling power from ther portfolio to the market. When highly subsidised, electrolysers provide less upward-flexibility to the power system (reducing consumption or selling power from their portfolio). This translates into higher electrolytic hydrogen production and indirect emissions, while direct emissions from natural gas-based hydrogen decrease along with produced quantities. The magnitude of such effects varies across the 2040 energy system scenarios put forward, bringing relevant insights for policymakers regarding clan hydrogen subsidisation and regulation.

Conclusions

We conducted a 2040 EU case study modelling the impacts of electrolysis regulation and subsidisation on electrolysis flexibility incentives, which impacts costs and emissions of the whole energy system. Our findings enable to better understand the cross-sectoral implications of regulation and policy targeted at the hydrogen sector. We concurrently uncover the significant dependence of such effects on the future energy system expected, highlighting the importance of coordinating hydrogen economy development, deployment of renewable or low-carbon power generation, and clean hydrogen policy and regulation, paving the way for net-zero European energy systems by 2050.

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