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Policy Support for Electrolytic Hydrogen: Impact of Alternative Carbon Accounting Rules

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Governments worldwide have recently launched policy support programs for hydrogen, where the level of support is to be tied to the carbon intensity of the hydrogen produced. Here we analyze the impact of alternative accounting rules for assessing the carbon intensity of electrolytic hydrogen on the financial and emission performance of Power-to-Gas (PtG) systems. Contrary to common beliefs, we find that more stringent accounting rules provide investors with sufficient incentives to invest in PtG systems today. Yet, they can still lead to life-cycle average carbon intensity levels close to those for hydrogen produced from natural gas with carbon capture. Less stringent rules generally entail higher investment incentives but also significantly higher emissions. Overall, our findings reflect the incentives for investors to utilize capacity by procuring additional, carbon-intensive electricity from the general grid.

Governments around the world have recently launched support policies for electrolytic and other low-carbon hydrogen production technologies[1,2]. These policies aim to accelerate the transition to a decarbonized economy, particularly in hard-to-abate sectors such as steel, chemicals, and heavy transportation[3,4]. Since the abatement potential of electrolytic hydrogen hinges on the emissions embodied in the electricity converted via Power-to-Gas (PtG) processes, governments in the United States (US), the European Union, and other regions have tied the level of policy support to the carbon intensity of the hydrogen produced. Yet, it remains a topic of intense debate how to assess this carbon intensity and thereby determine the level of support[5-7].

This paper examines the impact of alternative accounting rules for assessing the carbon intensity of electrolytic hydrogen and thus the level of policy support for PtG systems. In the debate on this topic, the common belief is that more stringent rules incentivize electrolytic hydrogen production during periods of abundant renewable energy and thus result in lower emissions than hydrogen production from natural gas. Yet, more stringent rules might also starve PtG systems as long as abundant renewable energy remains infrequent, thereby limiting incentives for initial investments. Our analysis shows how alternative rules shape the trade-off between the profitability of PtG systems and the average carbon intensity of the hydrogen produced over the life cycle of these systems.

In alignment with Europe, US regulators during the Biden administration have recently announced plans to base the assessment on multiple pillars that increase in stringency over time. Accordingly, any renewable electricity that investors seek to credit to the produced hydrogen is to be deliverable

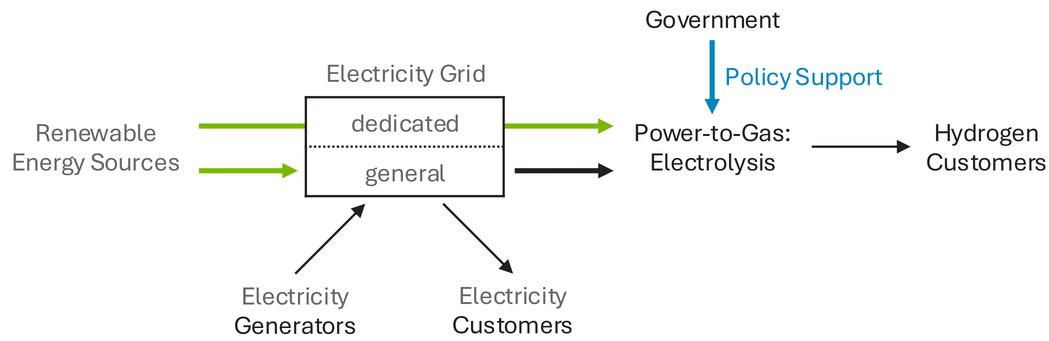

Figure 1. **Setting.** This figure illustrates the techno-economic setting of the PtG system considered in our analysis.

to PtG plants and incremental to the existing renewable energy supply in the market. For hydrogen produced before 2030, the temporal matching of electricity generation and hydrogen production is to be assessed on an annual basis, as is the carbon intensity of the produced hydrogen. For hydrogen produced thereafter, the electricity matching is switched to an hourly basis. Investors can further choose to assess the carbon intensity of hydrogen on either an annual basis or an hourly basis, provided that the corresponding annual average does not exceed a certain threshold. As of this writing, the US Congress has voted for a significant reduction in the duration of the policy support for hydrogen and other clean energy technologies. In particular, the policy support for hydrogen is now set to be available for investment projects, the construction of which begins before January 1, 2028. The envisioned pillars for assessing the carbon intensity of the hydrogen produced, however, appear to have remained unchanged.

We initially calibrate our economic model to reference plants eligible for the production tax credit specified in the Inflation Reduction Act in the current economic context of the US (see Figure 1). Contrary to common expectations, we find that the hourly carbon accounting rules provide investors with sufficient incentives to invest in PtG systems today, with internal rates of return between 8.6-14.7% for hydrogen sales prices between $1.0-3.5 per kilogram (kg) (see Figure 2). Yet, they also result in life-cycle average carbon intensity levels between 0.1-8.7 kg of carbon dioxide equivalents per kg of hydrogen (kg CO_2e/kg H_2). These estimates are

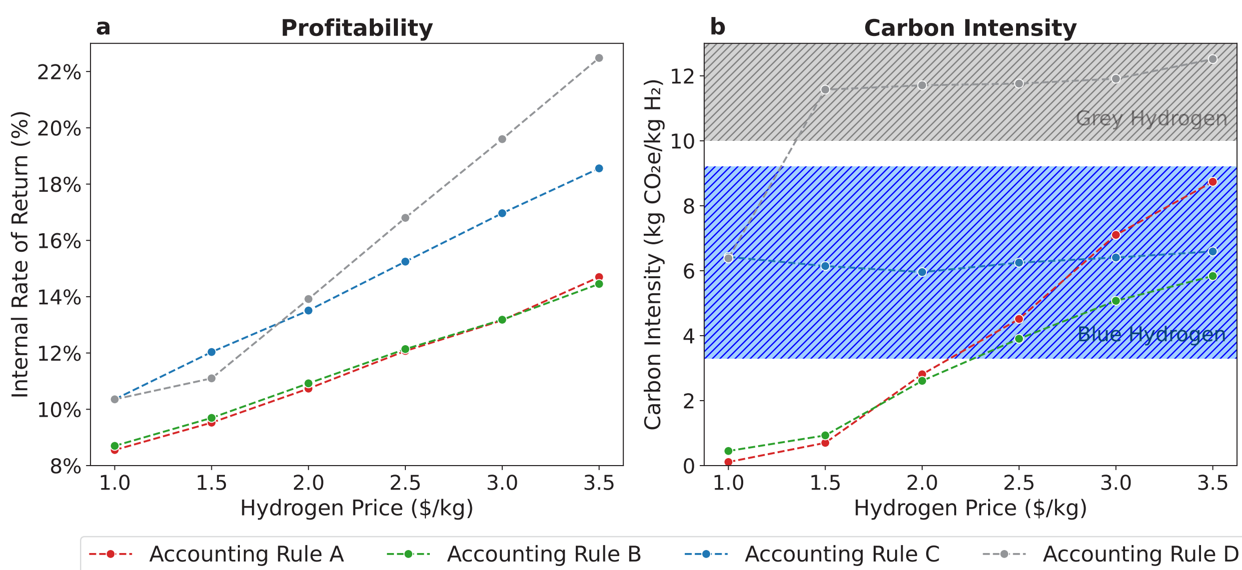

Figure 2. Life-cycle performance under different carbon accounting rules.
This figure shows the impact of accounting rules A (hourly tax credits), B (annual tax credits), C (incremental renewable energy) and D (non-incremental renewable energy) on (a) the profitability of PtG systems, and (b) the life-cycle average carbon intensity of hydrogen, given hydrogen prices between $1.0/kg and $3.5/kg. The dots show our point estimates at specific hydrogen prices, while the dashed lines interpolate between them for illustration.

lower than those for conventional "grey" hydrogen but, for hydrogen prices above $1.5/kg, comparable to those for "blue" hydrogen produced from natural gas with carbon capture[8,9]. The surprisingly wide range of estimates emerging from our analysis reflects the incentives for investors to utilize capacity by procuring increasing amounts of carbon-intensive electricity from the general grid as hydrogen prices rise (see Figure 3). This effect becomes particularly pronounced once the tax credit eligibility expires after the first ten years of an investment.

We further find that the annual carbon accounting rules lead to significantly higher profitability of PtG systems, with internal rates of return between 10.4-22.5% for hydrogen prices between $1.0-3.5/kg (see Figure 2). These upper estimates lie substantially above the typical range of investment returns available for renewable energy infrastructure, which speaks to the frequently voiced concern that tax credits of up to $3.0/kg could lead to excessive returns for investors. Our calculations also project significantly higher life-cycle average carbon intensity levels between 6.0-12.5 kg CO_2e/kg H_2. The lower end of this range falls right in the middle of estimates for blue hydrogen, while the upper end is comparable to lower estimates for grey hydrogen. The higher estimates for both profitability and carbon intensity now reflect the incentives for investors to convert substantially more carbon-intensive electricity from the general grid, both during and after the tax credit period (see Figure 3).

Our paper contributes to the emerging literature on the role of carbon accounting in determining the effectiveness of climate policies[10,11]. In particular, most recent studies on the policy support for electrolytic hydrogen consider a (central) planner seeking to minimize the total cost of an energy system subject to meeting given demands for electricity and hydrogen[5-7]. These studies then assess changes in the total cost and emissions of the system depending on whether the hydrogen demand is met by converting (non-) incremental renewable energy on different temporal intervals. In contrast, our analysis takes the perspective of a representative investor seeking to maximize the net present value of investments in PtG systems in response to policy support for electrolytic hydrogen. This approach enables us to examine how the financial and emission performance of PtG systems is shaped by alternative accounting rules. Such an analysis has been missing in the literature.

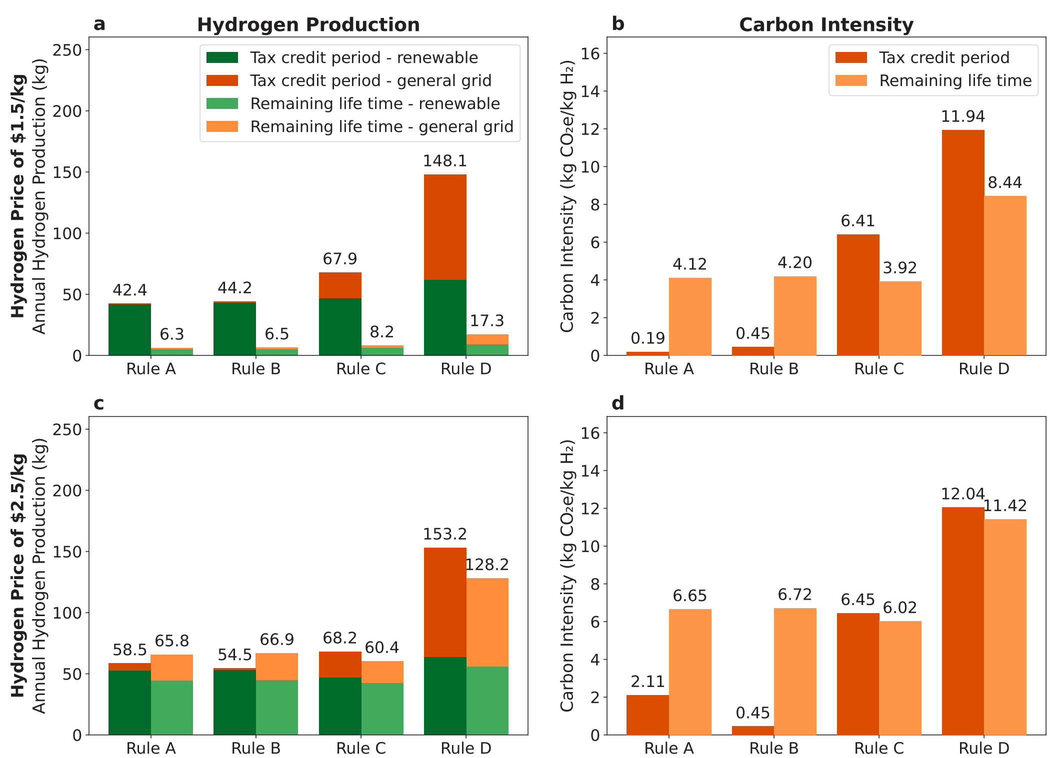

Figure 3. Life-stage performance under different carbon accounting rules.
This figure shows the impact of accounting rules A (hourly tax credits), B (annual tax credits), C (incremental renewable energy) and D (non-incremental renewable energy) on (a and c) the annual hydrogen production and (b and d) the annual carbon intensity of hydrogen, given hydrogen prices of $1.5/kg and $2.5/kg. Annual hydrogen production is calculated based on a renewable power generation capacity of 1.0 kilowatt peak.

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Link to the full working paper discussed in this brief:

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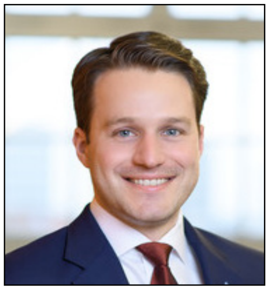
About the Authors



Gunther Glenk is an Assistant Professor of Business Administration at the University of Mannheim. His research examines the managerial economics of climate and sustainability. Topics include the accounting for corporate emissions, the cost of corporate decarbonization, and the incentives for climate action. Recent work has focused on the competitiveness of climate technologies, such as green hydrogen, energy storage, and electric mobility. Professor Glenk received his B.Sc., M.Sc., and Doctorate in Management and Technology from the Technical University of Munich.

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