Short-Run Marginal Emission Factors Neglect Impactful Phenomena and are Unsuitable for Assessing the Power Sector Emissions Impacts of Hydrogen Electrolysis*

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Abstract

This comment reacts to Runhau and Schiele's (2023) assessment of the cost and emissions impacts of electrolytic hydrogen production operating under different green hydrogen certification requirements in the EU. We critique the paper's use of short-run marginal emissions rates to estimate emissions impacts, a methodology which the literature has shown to be inadequate for assessing the full lifecycle emissions impacts of electricity sector interventions. We hope that our response clarifies the need to consider induced structural change when assessing the greenhouse gas emissions impacts of electricity sector decisions at all scales.

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1. Introduction

In a recent paper published by Ruhnau and Schiele [1] in *Energy Policy*, the authors assess the impacts of an EU policy requiring that electrolysis-derived hydrogen must be produced simultaneously with the clean electricity it claims as an input in order to qualify as a 'zero-carbon' fuel. One of this paper's stated objectives is understanding the effect this simultaneity requirement has on power sector emissions resulting from the production of clean hydrogen. Based on their modeling of a hypothetical wind-coupled hydrogen production facility in Germany, the authors concluded that relaxing the simultaneity requirement is unlikely to increase power sector emissions.

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However, the method employed to assess emissions outcomes in the Ruhnau and Schiele [1] analysis omits important phenomena — the omission of which is contrary to much existing guidance on evaluating electric-sector projects, and which we consider impactful enough to render the methodology unsuitable for assessing the emissions impacts of hydrogen certification policies.

2. How Short-Run Marginal Emissions Fall Short

Specifically, the paper used short-run marginal emissions rates to estimate the emissions impacts of hypothetical projects. By definition, short-run marginal emissions rates estimate how changes in electricity consumption would affect total grid emissions, exclusively considering impacts on the operations of the grid as it exists at some specific moment in time. Crucially, they neglect how the project would influence the structural evolution of the grid, i.e., the deployment and retirement of capital assets, such as electric generators and transmission lines. In other words, short-run marginal emissions rates are incomplete descriptions of the consequences of consuming or producing electricity. Large new consumers like the hydrogen electrolysis projects studied in Ruhnau and Schiele [1] can substantially influence the structural evolution of the grid in multiple ways, including the following examples:

- If an electrolysis project purchases electricity from the grid, the additional demand may induce generators to be built that would otherwise not have been, or may forestall retirements that would have otherwise occurred. There may or may not be a direct contractual relationship between the new generators and the hydrogen producer. Because the project with relaxed simultaneity requirements in Ruhnau and Schiele [1] purchases grid electricity during times of low wind generation, it is more likely to induce non-wind generators to be built and run.
- If an electrolysis project sells excess electricity to the grid, it depresses the value of electricity during those times and may cause a generator that would otherwise have been built to be delayed or entirely forestalled. Because the grid-connected projects in Ruhnau and Schiele [1] sell electricity to the grid when wind generation is high, these projects would be expected to disincentivize deployment of other generators,

and of other wind projects in particular due to their self-correlated output.

- An electrolysis project with purpose-built renewable generators necessarily occupies a site. By removing this site from the sites available for other projects, they potentially negatively influence the characteristics and economics of other projects. In some situations, by removing a high-quality site from those available to the broader power sector, the total amount of wind generation deployed to supply other power sector demands may be reduced. In this way, even the "island" (non-grid connected) project explored in Ruhnau and Schiele [1] analysis may not be fully additional.
- There may be policy effects not captured by short-run metrics. For instance, all of the projects analyzed in Ruhnau and Schiele [1] have the potential to interact with the EU's Emissions Trading System, and by doing so influence investment decisions both within the power sector and beyond it.

These phenomena are most clearly relevant for large changes in electricity consumption, such as the amount of electrolysis-based hydrogen production possible in the EU's future [2]. Ruhnau and Schiele [1] do mention this as a potential limitation of project-level analyses, which naturally focus on outcomes at smaller scales than system-level analyses. However, we stress that the phenomenon of induced structural change is present at any scale, and therefore that even an analysis of a single project would need to capture how that project could influence the structure of the grid, if the analysis wishes to comprehensively estimate the project's impact. This need is all the more critical when analyzing a policy with the potential to influence the design and operation of a large number of projects.

Existing guidance from multiple disciplines recognizes the importance of induced structural change. For example, the Greenhouse Gas Protocol's 2007 guidance for estimating greenhouse gas impacts from grid-connected electricity projects instructed analysts to estimate both operational and structural impacts [3]. Guidance from the lifecycle analysis community has stated that including both operational and structural impacts of electric-sector interventions is the theoretically correct approach for consequentialist life cycle analysis [4]. Most recently, one of the fundamental principles given in the National Standard Practice Manual for conducting electric-sector cost-benefit analyses is for the analyses to incorporate long-run impacts over the full life cycle of the resource being analyzed [5].

3. Evidence from the Literature

In addition to the above guidance, research has also demonstrated that the omission of these potential induced structural changes can significantly impact results. Hawkes [6] found that analyses based on short-run marginal emissions were liable to significantly overestimate the emissions impacts of heat pump deployment in the UK. Whereas a short-run analysis would implicitly assume that marginal fossil plants supply all new heat pump electricity demand, taking structural impact into account revealed that much of this demand would be instead supplied by new renewable energy sources brought online to meet growing demand. More recently, Gagnon and Cole [7] used a capacity expansion model (which simulates the structural evolution of the electricity system) to assess the emissions impacts of various electricity sector interventions, and likewise found that short-run marginal emissions rates systematically overestimated the emissions induced by load, often quite significantly, in large part because the short-run analysis methods' omission of induced structural change tends to ignore the role of new-build renewable generators in meeting new electricity demand. Most recently, Holland et al. [8] studied decarbonization and electrification in the long-run and found results that "differ in surprising ways from short-run intuition."

In the context of hydrogen production, Ricks et al. [9] used a capacity expansion model to assess the consequential system-level impacts of relaxed simultaneity requirements in the US, and found in contrast to Ruhnau and Schiele [1] that, for the system studied, non-simultaneous clean power procurements were ineffective at reducing the power sector emissions induced by electrolysis. This outcome was a result of the deployment of renewable generators for hydrogen production discouraging the deployment of similar renewable generators by third-party developers, a capacity substitution effect which is impossible to observe using a short-run analysis. The Ricks et al. [9] study further explored the effectiveness of using short-run marginal emissions rates as a metric to assess the overall emissions intensity of hydrogen production, and found that a clean energy procurement strategy based on this accounting system was ineffective at mitigating emissions.

4. Conclusion and Policy Implications

In sum: no method is perfect, but there must be a threshold below which a methodology becomes inappropriate for drawing comprehensive conclusions about the impacts of policies. We contend that the omission of known important phenomena in short-run methodologies make them unsuitable for making comprehensive estimates of electric-sector emissions impacts of hydrogen electrolysis or other significant changes in electricity consumption or procurement practices.

While this letter critiques the Ruhnau and Schiele [1] paper specifically, we were motivated to write it in part because similar short-run methods have likewise been deployed in other recent analyses seeking to assess the impacts of clean hydrogen policies, corporate greenhouse gas accounting standards, and various new forms of electricity demand [10, 11, 12, 13, 14]. We hope to motivate a discussion of the limitations of short-run methods beyond just this single paper.

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