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Calculating Life-cycle Emissions from Electricity Consumption

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U.S. Department of Energy

1000 Independence Ave, SW

Washington, DC 20585

To whom it may concern:

On behalf of Resources for the Future (RFF), I am pleased to share the accompanying comments to the Department of Energy on the Clean Hydrogen Production Standard.

RFF is an independent, nonprofit research institution in Washington, DC. Its mission is to improve environmental, energy, and natural resource decisions through impartial economic research and policy engagement. RFF is committed to being the most widely trusted source of research insights and policy solutions leading to a healthy environment and a thriving economy.

While RFF researchers are encouraged to offer their expertise to inform policy decisions, the views expressed here are those of the individual authors and may differ from those of other RFF experts, its officers, or its directors. RFF does not take positions on specific policy proposals.

These comments focus on the issues surrounding attributing emissions from electricity consumption as part of a life-cycle calculation of emissions from hydrogen production. Similar comments also appear in RFF's blog post:

https://www.resources.org/common-resources/how-can-hydrogen-producers-show-that-they-are-clean/

The authors of these comments are:

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If you have any questions or would like additional information, please contact Aaron Bergman at **abergman@rff.org**.

Sincerely,

Aaron Bergman, Brian Prest, and Karen Palmer

Calculating Life-cycle Emissions from Electricity Consumption

The Department of Energy has proposed a Clean Hydrogen Production Standard of 4 kg CO_2e/kg H_2.[1] In contrast to the definition of clean hydrogen in the IIJA, which looks at emissions produced at the site of hydrogen production, this standard involves a life-cycle calculation of the emissions associated with hydrogen production. In these comments, we will explore the choices that one must make in calculating life-cycle emissions from electricity consumption. This standard can only be met if the emissions associated with the consumed electricity are extremely low. For a polymer electrolyte membrane with an electricity consumption of 55 kWh/kg H_2,, we calculate an implied grid intensity of 0.07 kg CO_2e/kWh. For reference, the carbon intensity of the grid (*not* including upstream emissions from natural gas and coal production) is roughly 0.4 kilograms of carbon dioxide equivalent per kilowatt-hour. In other words, the electricity consumed must have emissions that fall short of the current grid average by more than 80 percent to achieve this standard.

In these comments, we will focus on the question of electricity emissions. However, there are other important decisions when determining life-cycle emissions. For example, one must choose:

- Which global warming potential to use for each greenhouse gas emitted, given that global warming potentials vary depending on timescale and as our understanding of the science progresses?
- How to account for the fact that hydrogen itself is an indirect greenhouse gas and what value one should use for its GWP?
- How can a consumer of natural gas demonstrate that their leakage rate is lower than the national average as part of their life-cycle calculation?

With respect to electricity, we focus on two related questions. The first is, what emissions are associated with consuming energy from the grid? This determination is not as straightforward as one might think. The second is, how can a consumer demonstrate that they are consuming electricity that's cleaner than the grid average? Both of these questions are fundamental to the definition of life-cycle emissions.

What Emissions Are Associated with Electricity from the Grid?

Various public and private organizations have undertaken major efforts to estimate the carbon intensity of electricity consumption at different times and places.[2] This topic has been the subject of years of discussion, including in the Greenhouse Gas Reporting Protocols for Scope 2 Emissions.[3] In fact, the grid's carbon intensity varies from instant to instant given the real-time nature of electricity delivery, which makes grid intensity exceedingly difficult to measure with confidence.

In addition, the *average* carbon intensity of a grid is distinct from the grid's *marginal* intensity. The average carbon intensity is the simpler concept, equally attributing electricity emissions to all consumers at a given place and time based on their consumption. Average emissions rates typically are used for greenhouse gas accounting, but they do not represent how much emissions would be *caused by* an incremental amount of

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[1] This standard is the same as the highest amount of life-cycle emissions allowed to receive the 45V tax credit for hydrogen production.

[2] See, for example, **https://www.rff.org/publications/reports/options-for-eia-to-publish-co2-emissions-rates-for-electricity/**

[3] **https://ghgprotocol.org/scope_2_guidance**

electricity consumption. This latter concept is known as the marginal emissions rate. For example, if an increase in consumption is served by a natural gas generator that increases its output, the gas generator's emissions intensity is the relevant marginal metric. Alternatively, if electricity from renewable energy that might not be otherwise consumed (e.g., "curtailed electricity") is used to generate hydrogen, then the marginal emissions rate would be zero, and the hydrogen might be thought of as carbon free.

With both metrics, one has to decide which timescale to apply (given that the metrics vary with time) and what regional scale to use. In addition, if one uses the marginal rate, it will be challenging to define and estimate that rate precisely. The US Energy Information Administration has been tasked by the 2021 Bipartisan Infrastructure Law to collect and report data on the average and marginal emissions intensity of the US grid at geographically and temporally granular levels. If and when the Energy Information Administration delivers on this ambitious goal, one could use that data to quantify the emissions intensity of electrolysis, which otherwise cannot be estimated. However, to date, no data set on marginal emissions rates has been endorsed officially by the US government.

Although the Energy Information Administration recently has released hourly estimates of national average emissions rates,[4] this information alone is unlikely to be useful for these purposes for several reasons. One such reason is that, in the four years during which the data has been reported (2018 to present), the national average emissions rate has not fallen below the most lax threshold in Table 1 for even a single hour.

How Can a Consumer Demonstrate Their Consumption of Clean Electricity?

One might assume that reducing carbon intensity could be possible through direct consumption of carbon-free energy, in lieu of consuming power directly from the grid. In practice, the situation is not so straightforward. Due to the physics of electricity, one cannot ascribe electricity consumed at one point on the grid to any particular generator. As a result, the only way to physically demonstrate the consumption of clean electricity is to establish a direct connection between the generator and consumer, in the absence of any connection to the rest of the grid.

Establishing such direct connections will not be practicable for consumers in general; instead, several approaches have been developed to demonstrate the consumption of clean electricity. The first is a power purchase agreement, in which a consumer purchases clean power directly from a generator, with both consumer and generator on the same grid. With a power purchase agreement, the consumer counts the consumption of clean power only during the hours when the generator is generating, which may be a limited number of hours due to the low capacity factor for renewable generation. Some providers are exploring contracts that combine the output from many clean generators and storage into a composite product that yields clean energy with a high capacity factor. So-called "virtual" or "synthetic" power purchase agreements[5] also are available, which do not involve the physical delivery of electricity to a consumer. Despite their name, these contracts mainly involve hedging price risk,[6] and the purchaser is not in fact consuming clean electricity in these settings.

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[4] **https://www.eia.gov/electricity/**

[5] **https://rmi.org/insight/virtual-power-purchase-agreement/**

[6] **https://www.rff.org/publications/working-papers/reducing-risk-merchant-wind-and-solar-projects-through-financial-hedges/**

Another method that some argue can demonstrate the consumption of clean power is through a renewable energy credit (REC)—or, more generally, a clean energy credit—which represents the clean attributes of the power generated and which can be traded. Such instruments exist and are used by US states to comply with renewable portfolio standards (RPSs). By "retiring" these "compliance RECs" so that they cannot be used for compliance with any other policy, additional clean energy must be generated to meet the RPS (if the RPS is binding), which thereby increases the overall amount of clean energy on the grid.

"Voluntary RECs" also exist, in which the credit cannot be used to comply with any state policy. Widespread skepticism exists[7] over whether acquiring and retiring these voluntary RECs has any substantive impact on clean energy generation. Some REC registries have begun to move to new instruments, known as Time-based Energy Attribute Certificates,[8] which can be used to attribute the supply of clean power to the location and hour of production. These new instruments may improve the situation, but more work needs to be done to demonstrate the associated impact on clean energy generation.

Even with compliance RECs, the effect on carbon emissions is not straightforward. For example, retiring a compliance REC does not guarantee that any additional clean energy will be contributed to the grid if the grid already contains more renewable energy than policy requires. Furthermore, many different definitions exist for what qualifies as "renewable energy" for a REC depending on the state, and some states offer more than one REC per unit of generation for specific types of generation. Many states also have alternative compliance payments, meaning that RECs can effectively be created by paying a fee instead of generating renewable electricity. As such, understanding how to translate RECs into carbon abatement is challenging, with any rigorous connection likely requiring more research.

Conclusions

Defining life-cycle emissions from electricity consumption is a difficult challenge, and the choices one makes when doing so will have far-reaching consequences for a potential hydrogen economy and subsequent emissions impacts, both of which may be large. An inevitable trade-off will arise in these considerations, between simplicity and accuracy, and each choice offers a different degree of rigor with respect to the real-world emissions that result from electricity consumption. We do not pretend that an optimal solution is easy to identify, and we continue to explore further research to inform these important questions. We hope that the Department of Energy and other executive branch agencies will seek out the best information available and that the department will ensure a rigorous evaluation of the trade-offs as it navigates this complex area.

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[7] See, for example, **https://www.nature.com/articles/s41558-022-01379-5**

[8] **https://www.wri.org/events/2022/8/tracking-and-verifying-247-carbon-free-energy-purchases**