The European green hydrogen strategy risks increasing CO_2 emissions globally

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Abstract

The EU comission has proposed a target of 20Mt of green hydrogen use per year in the EU, half of it being imported, the other half produced domestically. It also proposes additionality rules which should ensure that green hydrogen is low-carbon. We show here that this rules are ineffective in potential export regions, increasing CO_2 emissions there. Furthermore, CO_2 emission reductions in the EU are likely low, due to the European Emission Trading Scheme. In total, this implies that the hydrogen targets can increase global CO_2 emissions quite significantly. We therefore propose an adaptation of the rules for green hydrogen production.

The EU Commission has devised the RePower EU plan which, among other targets, aims to increase domestic production and imports of green hydrogen [1]. The plan was released soon after the Russian invasion of Ukraine that caused price spikes on all markets for energy commodities and significantly increased the risk of supply disruptions. As outlined in the plan, the EU aims at diversifying energy supply away from Russian gas, and build up a green hydrogen sector which is assumed to be important for the full decarbonization of the energy system in the long-term. Supporting the RePower EU plan, the commission is also proposing rules to ensure that the electricity used for production of hydrogen in electrolyzers comes from renewable sources, the so called "additionality" rules [2]. However, the commission proposal does not fully incorporate the impact of the European flagship CO_2 emission reduction instrument, the European Emission Trading Scheme (ETS), on hydrogen production and consumption and vice versa. Furthermore, the additionality rules are not able to ensure that green hydrogen is produced in a carbon neutral way in non-EU exporting countries. We show here that therefore a signficant overhaul of the associated rules will be required.

In detail, the EU plans to increase green hydrogen supply to 20Mt/year (660TWh/year) in the year 2030 [1]. Half of the quantity is planned to be produced in the EU and abroad, respectively, using green or low-carbon electricity for electrolysis. Furthermore, the commission is developing "additionality" rules to ensure that electricity used for hydrogen production comes from new renewable sources. They will apply to European as well as Non-European hydrogen producers. We show here, that these rules are not effective in guaranteeing emission reductions in production regions. Since global CO_2 emissions may increase due to the policy, at least in the short-term, we propose potential changes in regulation that will maximize the synergies between hydrogen production targets and CO_2 emission reduction targets.

1 Limited additionality from additionality rules

The European Commission proposal requires that any electricity used to produce green hydrogen has to come from new, additional renewable electricity generation to allow for carbon-neutral hydrogen production. In this context, the commission has proposed rules[1], which define under which circumstances hydrogen can be considered to be "green": (a) if the hydrogen-producing installation draws renewable power directly from renewable generation facilities, while no power comes from the public grid, (b) if the facility is located in a bidding zone where the share of renewables is above 90%, (c) if the electricity used for generating hydrogen would otherwise have been curtailed, or (d) if the facility enters in power purchase agreements with renewable electricity generators [2][2].

However, condition (b) will not ensure that no fossil fuel emissions are associated with green hydrogen production, simply because even in a system that hosts 90% renewables, the marginal generation can still be fully fossil. Furthermore, an increase in utilization of renewables in the zone may decrease exports of electricity, increasing marginal emissions elsewhere in the system. At the same moment, conditions (a) and (d) rely on the proof of the expansion of renewable capacities. While these rule can ensure that the produced hydrogen relies on new green power generation, it cannot guarantee that the expansion of low-carbon power generation capacities for hydrogen production does not compete with the expansion for other purposes, such as grid decarbonization. In that case, emission savings can be lower than under a baseline without hydrogen production, unless other policies which enforce emission reductions are in place (see section 2).

The reasons is that there may simply be insufficient resources in terms of workforce, capital, or land that can be mobilized in the short period of time until 2030 to expand both renewables for hydrogen production and for other

[1]The rules are still under heavy discussion, we rely here on the latest proposal from the 10th of February 2023 [2]

[2]The regulation is much more detailed and, e.g., stresses that hydrogen is only considered "green" when using public grid electricity if electrolyzers are turned on when renewable capacities generate. Hourly matching, however, is going to be likely postponed to 2030. The implications of different matching schemes are discussed in detail by Zeyen et al. [3].

purposes. About 1200 TWh of electricity are necessary to produce 20 Mt of hydrogen, once efficiency losses from electrolyzers and transport are incorporated[3]. To put this into context: this is about 2.7 times the annual global expansion of solar PV and wind power generation in the year 2021 [4], i.e., a very significant volume globally. However, limits in the expansion rates of renewables are already hit today: for instance, in Germany, quantities demanded were higher than quantities offered in all auctions of open-field solar PV and onshore wind in 2022 [5]. More generally, a study of solar PV and wind power growth rates showed that observed and projected growth rates in renewable energies are insufficient to reach 1.5°C targets [6]. Therefore, using renewable capacities to produce hydrogen may directly compete with decarbonizing power generation and electrification, potentially increasing emissions.

In the following, we explain in more detail how green hydrogen production can increase CO_2 emissions in the production region compared to a baseline scenario. For that purpose, we introduce an additionality factor (β), which measures the share of renewable electricity in total renewable electricity needed to produce hydrogen which is installed additionally to an alternative baseline. We assume a non-EU country (see Figure 1) has built no renewable electricity generation at all so far and relies solely on coal power, producing 2000 TWh of electricity at 1 $t_{\mathrm{CO2}} MWh^{-1}$. The country starts, in 2023, building renewables to produce hydrogen and export it to the EU. The hydrogen producer will acquire sufficient PPAs to certify the produced hydrogen as green. However, renewable electricity generation would not be additional to domestic production, if otherwise the country would have used the same renewable generation capacities to decarbonize, e.g., electricity generation in the country. In this case, $\beta = 0$. Consequently, this lack of domestic decarbonization due to hydrogen exports can be interpreted as additional emissions caused by the EU hydrogen policy. Full additionality, in contrast, would occur if the country builds the renewable generation necessary for hydrogen production on top of the baseline expansion, shown as $\beta = 1$ in Figure 1.

Low additionality of $\beta = 0$ may occur if the expansion of renewable generation capacity in a particular country is bounded from above by C per year due to institutional and technical constraints. The country initially plans to expand all of C to decarbonize its power sector. In that case, if an investor decides to build a hydrogen production facility, there would be no additionality, i.e., $\beta = 0$, as C is a fixed upper bound. In contrast, full additionality, i.e., $\beta = 1$, is for instance possible, if the expansion of low-carbon energies in a country is mainly constrained by capital or technology availability, and if these constraints can be relaxed, e.g., by foreign investments into hydrogen production. Furthermore, if grid restrictions limit the expansion of renewable electricity, stand-alone electricity generation to produce hydrogen may be less constrained than generation facilities used to decarbonize fossil fuel power generation on the grid, implying that $\beta > 0$.

The effect of low additionality on emissions can be substantial: if instead of

[3]Assuming an electrolyzer efficiency of 70% and transportation losses of 20%

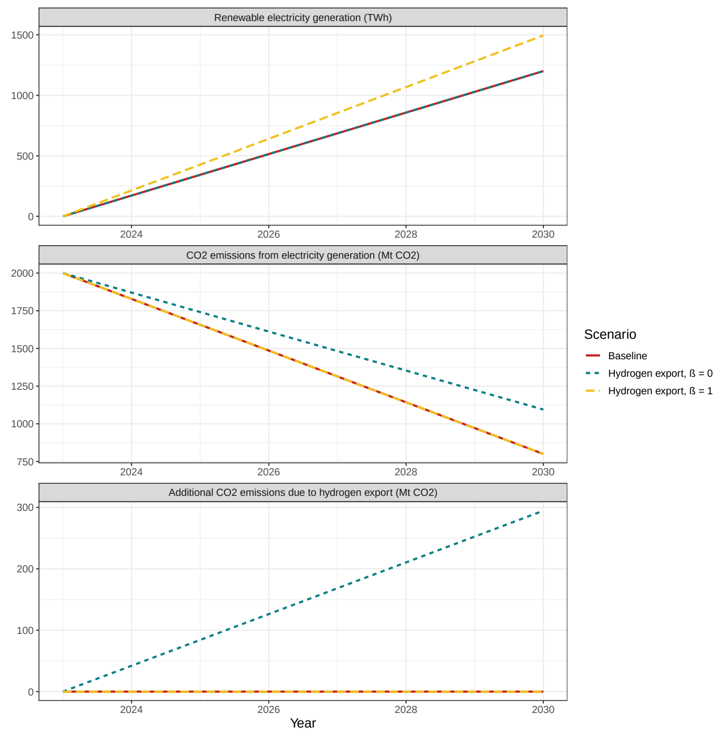

Figure 1: Renewable electricity generation in an imaginary exporting region, associated CO_2 emissions from electricity generation and additional CO_2 emissions due to hydrogen exports. Additionality β is the share of electricity generation required for hydrogen production which is built additionally to the baseline.

producing hydrogen, coal power was replaced by renewable electricity, additional CO_2 emissions caused by imported hydrogen at no additionality reach over 60% of the total EU CO_2 emission target for 2030 (see Figure 2). If electricity generation is already very clean in the exporting region and an additional unit of renewable electricity will substitute only 0.5 units of gas power generation[4], additional emissions would be at around 5% of the 2030 EU emission target at an additionality of $\beta = 0$. Of course, if the exporting country has a stringent target on CO_2 emissions, similar as in the ETS, additional hydrogen production will not increase CO_2 emissions – we discuss this effect in more detail in the next section.

[4]If the power system is already very clean, an additional unit of renewable electricity may not completely substitute fossil generation. It may be partly curtailed – or partly cycled through a short or long-term storage at total cycle efficiency as low as 50%. Thus, the marginal CO_2 emission reduction can be low.

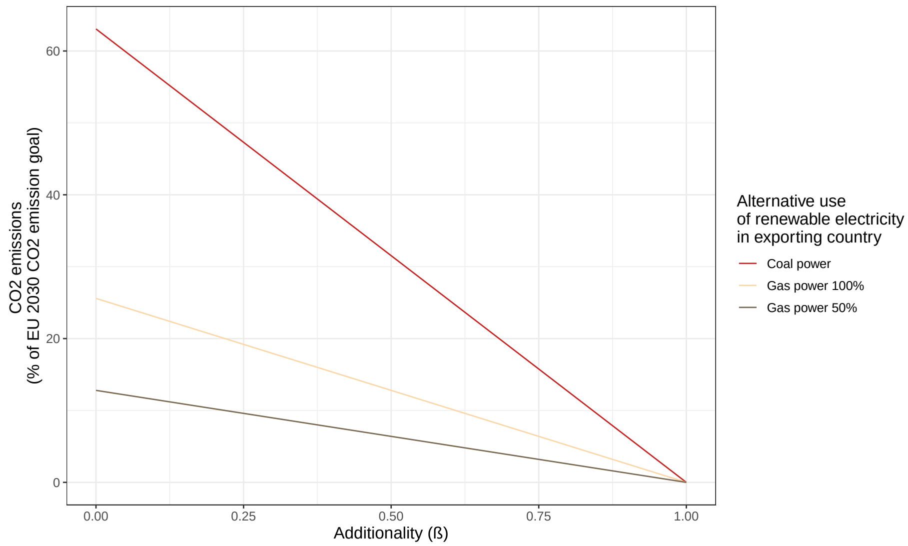

Figure 2: Additional emissions in exporting countries for different alternative uses of low carbon electricity and different values of real additionality. Note: Gas power 50% indicates that one unit of renewable electricity substitutes only 0.5 units of gas power.

2 Hydrogen targets and the EU ETS

Requiring that hydrogen is produced from additional renewable electricity should guarantee its carbon-neutrality. In the last section, we have shown that the EU additionality rules are not effective in guaranteeing additional renewable electricity generation and therefore carbon-neutrality. However, in regions where a strict cap on CO_2 emissions is implemented with the help of an ETS, by design, introducing hydrogen production to the system cannot increase CO_2 emissions. An ETS will, however, also imply that there will be no additional emission savings due to hydrogen consumption, as long as the hydrogen is used in sectors covered by the ETS – the so called waterbed effect [7]: emission reductions by one policy or sector allow to increase emissions in other sectors. This applies to short-term emission savings. In the long-term, the implementation of hydrogen targets may allow to decrease the emission cap in the ETS faster in subsequent trading periods due to technological learning set off by the policy (see section 3).

The EU has implemented an ETS. However, the theoretical results discussed above do not necessarily hold due to two particularities of the EU system: first, not all sectors where hydrogen can be consumed are currently covered by the ETS. And second, the EU has implemented a market stability reserve (MSR), which has, at least temporarily, 'punctured the water-bed' [7] and implies some flexibility in terms of total reductions of CO_2 emissions: due to the MSR, cumulative emission reductions in 2030 can be below the agreed final target value.

The interaction of the hydrogen targets with the MSR, and with sectors not covered by the ETS are complex. They will depend on the exact design of the ETS-II, which will cover transportation and buildings from 2027 on, but is expected to have a price cap [8], and on the rules for the MSR, even post 2030. A thorough assessment is beyond the scope of this comment, but we briefly discuss potential interactions: (a) if the implementation of the hydrogen targets increases CO_2 allowance prices in the ETS, CO_2 emissions in the EU will likely go up, because higher prices imply a lower potential of canceling allowances in the MSR, and they may cause potential leakage effects to sectors covered by the ETS-II, which has a price cap[5]. (b) Lower prices will imply the opposite.

Imported hydrogen will strictly lower prices in the ETS, as it will increase the supply of low-carbon options, pushing the supply curve of emission reductions to the right. The impacts of domestically produced hydrogen are complex, as hydrogen production will make mitigation for other sectors more expensive (due to increased use of renewable electricity), while the produced hydrogen can lower emissions. As the overall efficiency of hydrogen in reducing CO_2 emissions in the short-term is lower than direct electrification, we expect an increase of emission allowances prices from domestic hydrogen production (see section 3). This has important policy implications we discuss in the last section.

3 Short and long-term policy impacts on mitigation cost

We have shown so far that the EU hydrogen strategy most likely will increase CO_2 emissions in exporting countries, at least in the short-term, and that impacts within the EU are complex. Most scenarios in the recent 6$^{\text{th}}$ Assessment Report by the IPCC [9] show lower hydrogen production volumes in the EU and in particular lower hydrogen exports from other regions (Figure 3), indicating that the hydrogen production targets are inefficient. While domestic production picks up quickly within the EU after 2030 at least in the most stringent mitigation scenarios, exports from the rest of the world (ROW) remain low until 2040. The simple reason for the ineffectiveness is that alternative uses of renewable electricity, in particular substitution of fossil power generation, save significantly more emissions than the hydrogen route (see Figure 4) – and that hydrogen production and use needs additional equipment, such as electrolyzers, hydrogen storage and hydrogen transportation equipment. As long as the power system in the EU hosts significant amounts of fossil power generation which can be substituted by renewables, the use of green hydrogen will therefore be more costly to achieve the same decarbonization effect.

[5]e.g. electrification of transportation and buildings may be lower if prices in the ETS are higher, as higher power prices are a consequence of higher ETS prices. In contrast, continued use of fossil fuels in transportation and buildings may be possible in ETS-II due to the implementation of a price cap and an associated release of emission allowances

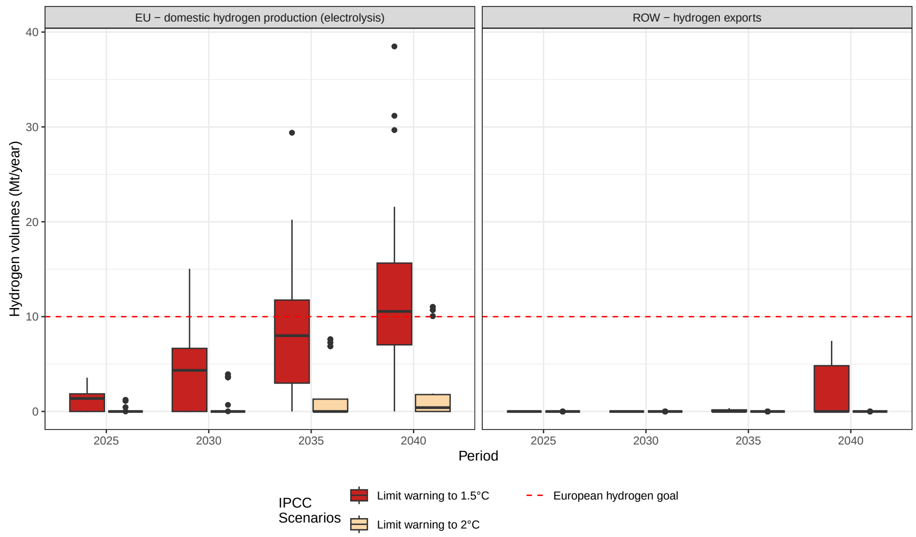

Figure 3: Annual domestic hydrogen production in the EU and annual hydrogen exports in the Rest of the World (ROW) in the scenarios from the 6^{th} IPCC Assessment Report [9], compared to annual EU domestic hydrogen production and hydrogen import targets in 2030.

This does not necessarily imply that the hydrogen targets should be abolished all together. Technology specific support policies for green hydrogen production may be necessary to benefit from the positive externality of technological learning [10], [11]: i.e. the currently larger costs and CO_2 emissions may be offset by rapid technological cost decreases, contributing to lower transition costs and to a higher transition speed to a carbon-neutral economy after 2030. The effect and the cost-effectiveness will depend on the impacts of technological learning on overall costs of the technology.

4 Update rules to maximize CO_2-emission reductions

We have shown that the EU hydrogen targets can increase global CO_2 emissions, at least in the short-term, as the additionality rules are ineffective in enforcing the use of additional renewable energy capacities. As the hydrogen targets may still be required to ensure long-term least cost decarbonization, we recommend to update rules to also minimize short term emissions.

First, the additionality rules for green hydrogen production should be dropped. They are complex, hard to monitor and will not necessarily contribute to increasing the expansion of renewable electricity above baseline.

Second, as a consequence imports of green hydrogen should only be possible

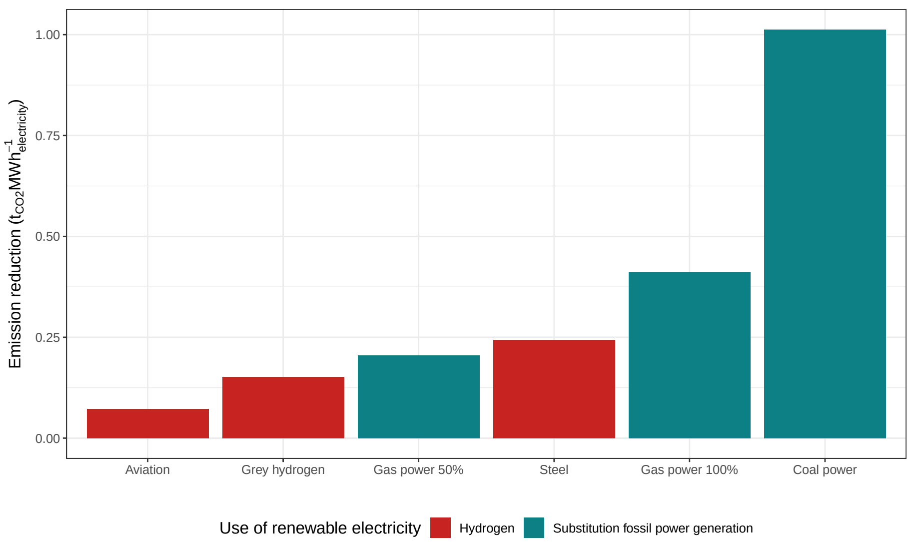

Figure 4: Reductions in CO_2 emission for potential hydrogen uses and direct use of electricity for substituting fossil fuel power generation. Note: Gas power 50% indicates that one unit of renewable electricity substitutes only 0.5 units of gas power (due to intermittency of renewables).

from regions, where an ETS is in place – or strict, binding CO_2 emission caps are enforced by other means. This will ensure that additional emissions from the exports of hydrogen to Europe are limited[6]. This will make the additionality rules in the comission's proposal obsolete, but limits potential exporters to either small countries or ones which will unlikely export large quantities of hydrogen as they face significant climate change mitigation challenges themselves[7]. The establishment of a hydrogen trading union could nevertheless be the seed for a climate club as suggested by Nordhaus[13], comparable to how the European Community for Steel and Coal served as the institutional foundation of the EU.

Third, the EU Comission should evaluate on a regular basis if the hydrogen production targets threaten overall CO_2 emission reduction targets by 2030. This may happen if subsidized hydrogen production uses so much of the potential low-carbon electricity generation expansion, that other sectors are unable to reduce emissions sufficiently. In that case, emission certificate prices may increase to a politically infeasible level, risking the release of additional certificates from the market reserve or even an increase in the CO_2 emission cap. This should be avoided by all means. The most effective way within the EU would

[6] There still could be leakage by a change in trade flows between the exporting country and third countries, though.

[7] According to De Clara et al.[12], the following countries have established ETS: China, Kazahstan, Korea, Mexico, UK, Switzerland, New Zealand, some states in Canada, some states in the US.

be to suspend the expansion of domestic hydrogen production for some time.

Fourth, the feasibility of the speed of the expansion of green hydrogen at comparable high rates in decarbonization scenarios has been questioned [14][8]. Furthermore, the benefits of the policy depend on the scale of potential technological learning. A thorough assessment of the feasibility and of the costs and benefits of the policy should therefore be conducted, before implementing the hydrogen targets.

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