RED II GREEN POWER CRITERIA - IMPACT ON COSTS AND AVAILABILITY OF GREEN HYDROGEN IN GERMANY

Short study for RWE AG

12 July 2021

"AT A GLANCE"

Green hydrogen is expected to play a central role in the energy transition. **However, it is currently unclear under which conditions hydrogen from grid-connected electrolysers will be recognised as "green".** Both the Renewable Energy Directive (RED II) and the Renewable Energy Act (EEG 2021) only define a framework for the purchase of electricity from renewable energy sources. Downstream legal acts need to be designed to put them into practice.

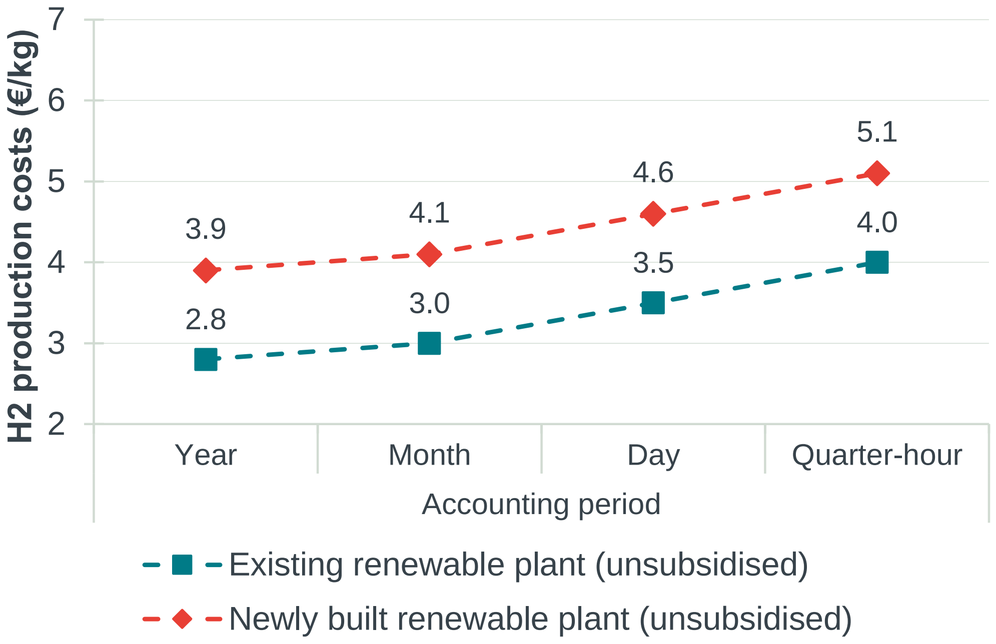
Even without any green power criteria, the costs of electricity-based hydrogen in Germany (approx. 2.6 €/kg) are significantly higher than those of grey hydrogen (1-1.5 €/kg) or blue hydrogen (2.0 €/kg), at least in the short to medium term. This implies a big challenge for the ramp-up of a German hydrogen industry.

If green power criteria are taken into account, hydrogen production costs rise even further, to **at least approx. 3 €/kg**, and quickly reach a scale of **4 - 5 €/kg** if the criteria are implemented very strictly (e.g. quarter-hourly accounting and renewable electricity production limited to new plants only). Under these strict criteria, the **availability** of renewable electricity to produce green hydrogen will also be restricted, which means that significantly less green hydrogen could be produced for a given electrolyser capacity. This is based on three factors:

- **Additionality** – Restricting allowed renewable electricity (RE) production to new plants means excluding (unsubsidised) existing plants and significantly restricting the potential of renewable power for hydrogen production. Depending on the relevant market situation, green hydrogen production costs of existing plants can be considerably below those of new RE plants.
- **Temporal correlation –** If the temporal correlation between RE generation and use by the electrolyser (accounting period) is less strict, this will lead to an increase in electrolyser utilisation and a decrease in costs. Long accounting periods (e.g. annually) allow for a considerable reduction in hydrogen costs compared to short accounting periods (e.g. quarter-hourly). For example, we calculate a reduction of 0.7 €/kg or 20% for existing onshore wind power plants. Long accounting periods also guarantee the additionality of green power generation in general. The effects on greenhouse gas emissions relative to short accounting periods are unclear and are likely to play a minor role.
- **Geographical correlation** - The demand for a geographically close correlation between RES-E and H2 production increases costs and uncertainty for investors. Location incentives for electrolysers should be appropriately designed and timed in order to prevent them from disturbing the market ramp-up of hydrogen.

Consequently, a **successful market ramp-up of green hydrogen** requires a **pragmatic definition** of the green hydrogen production criteria. To make it easier to get started, the requirements of the green power criteria could initially only apply to part of the electricity used in the electrolysers, or they could be tightened gradually over time as the competitiveness of green hydrogen increases. In addition, the suitability of the green power criteria should be examined in the context of strongly increasing shares of renewable energies in the electricity mix.

Figure: H_2-production costs in different accounting periods for existing and new plants (example: combination of PV/wind)



Source: Frontier Economics
Note: Calculations based on electricity prices and profiles in 2019.

SUMMARY

Green hydrogen as a pillar of the energy transition requires a clear definition of criteria

The share of renewable energies in electricity generation has significantly increased in recent years in Germany. But achieving Germany's and the EU's medium- and long-term climate goals will also require the decarbonisation of the industrial, mobility and heating sectors. As stated in the German government's national hydrogen strategy, green hydrogen can play a significant role.

However, it is currently unclear which criteria must be fulfilled to produce hydrogen from grid-connected electrolysers to be recognised as "green". RED II only defines conditions for the recognition of green hydrogen and the downstream products (e.g. electricity-based diesel, petrol, etc.) as renewable energies in the transport sector. These are expected to be defined in more detail by the end of 2021 in the form of a delegated act by the EU. Similarly, § 93 of the German Renewable Energy Act (EEG 2021) does not contain any specific requirements for green hydrogen. Rather, these are still to be defined in more detail within the respective regulatory frameworks. However, it can be assumed that the requirements for green hydrogen in the transport sector (which are still to be defined under RED II) will also apply to other sectors and possibly even serve as a blueprint for the EEG regulation. In short, these requirements will build an important basis for a successful market ramp-up of the hydrogen industry.

Conditions for the purchase of electricity to produce green hydrogen

The current discussion on the design of the RED II framework conditions and the still undefined provisions of § 93 EEG shows that the criteria for green hydrogen must meet several requirements. First, from an overall economic perspective, the production of green hydrogen should effectively contribute to reducing greenhouse gas emissions and be integrated into the energy system at reasonable costs. Second, the market ramp-up can only be effective if the electricity procurement criteria prevents insufficient availability of corresponding RE quantities or high production costs of green hydrogen. Otherwise, it might be impossible to produce sufficient hydrogen, the industry might not accept it or it might require considerable subsidies from the public sector.

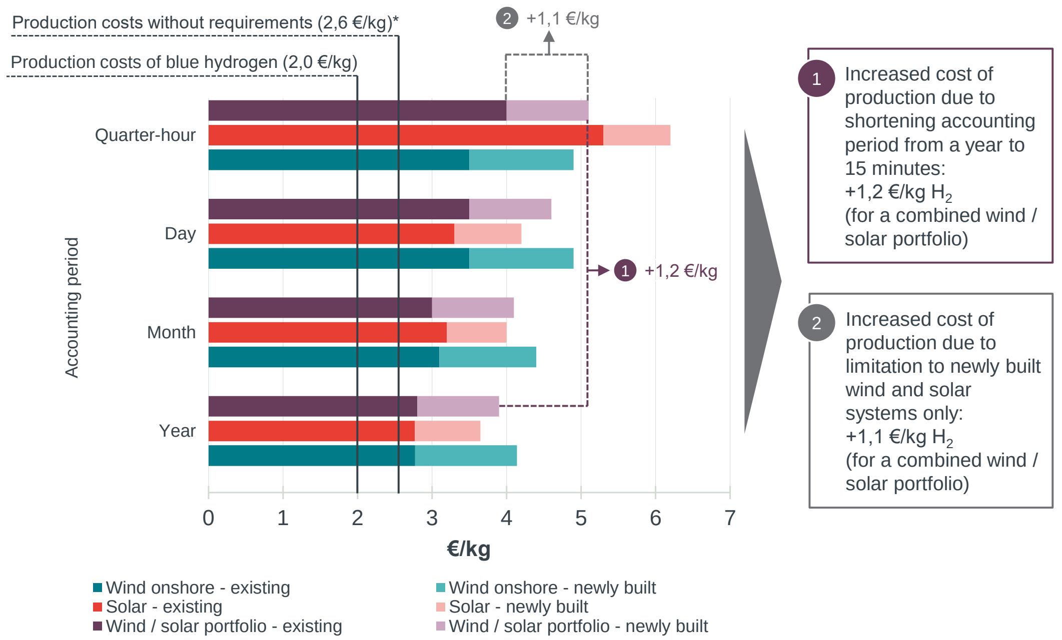
The extent to which a direct, bilateral relationship between the RE plant and the electrolyser is required, e.g. in the form or a direct supply contract, is of great importance. In principle, it would be sufficient to prove the renewable nature of electricity through Guarantees of Origin (GOs). The GOs would prove that the amount of electricity used to produce green hydrogen was generated from renewable energy sources. As part of the upcoming RED II reform, the current GO system might be expanded by further verification requirements, e.g. to include temporal or geographical correlations and only allow GOs that meet these criteria. In this study, Frontier Economics assumes a direct correlation between RE plant and electrolyser, based on the political discussion to date.

Frontier Economics was commissioned by RWE AG to explore the impacts of different criteria design options on the production of green hydrogen:

- **Additionality:** Which plants can be used to purchase electricity to produce green hydrogen to make sure that the RE power is additional? We look at the use of surplus electricity, power from unsubsidised existing plants and electricity from existing plants that are no longer being subsidised.
- **Temporal correlation:** How temporally proximate should the production of renewable power and the production of hydrogen be? We look at different periods, from quarter-hourly match to an at least monthly match. And for some cases, we also look at yearly matches.
- **Geographical correlation**: What should the geographical proximity between the production of renewable electricity and the production of hydrogen be? In particular, we will look at the suitability of assuming unrestricted transport options within a bidding zone.

We have defined different design scenarios and calculated the respective production costs for green hydrogen for each of these scenarios. A summary can be found in **Figure 1**. We have also examined the available quantity potentials.

Figure 1 Hydrogen production costs in different production periods for existing and new plants (mixed profile – new RE plants for comparison)



Source: Frontier Economics

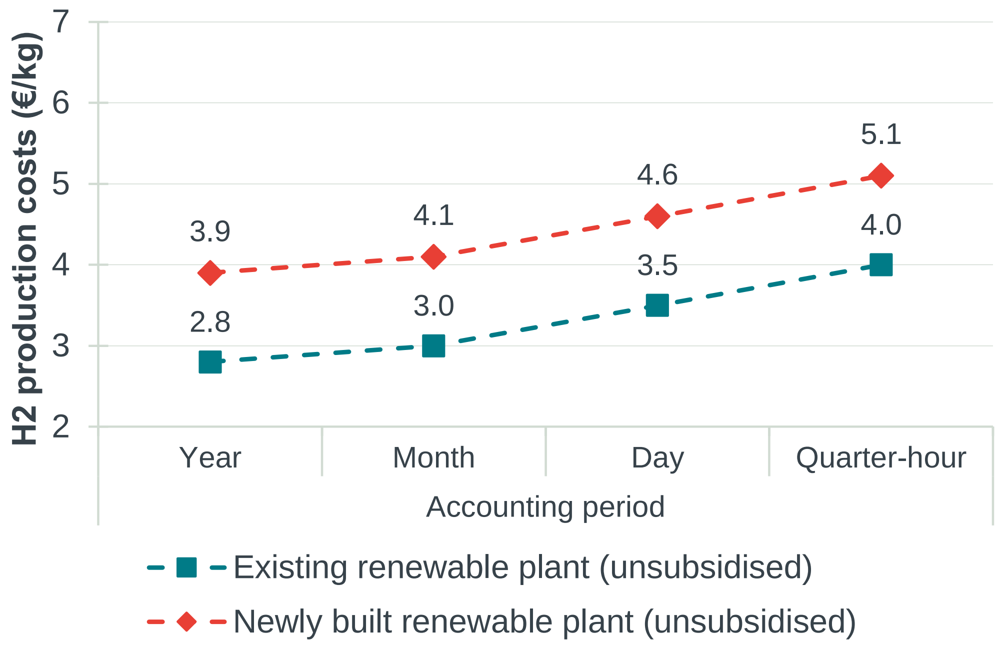
Note: *Calculations based on electricity prices and profiles 2019. The comparative value of blue hydrogen is based on the average value of the Hydex Blue Index for April 2021.*
**) Costs with market purchase and guarantee of origin 2.7 €/kg*

Additionality – Allowing unsubsidised existing plants will increase quantities and decrease costs

Our analysis gives the following results regarding the electricity supply sources permitted to produce green hydrogen:

- **Allowing unsubsidised existing plants can save considerable costs**: Depending on the electricity price level, the electricity procurement costs of unsubsidised new plants can be significantly higher than those of existing plants that do not receive subsidies. Specifically, the production costs of green hydrogen through the purchase of electricity from existing plants in the scenarios considered here are approx. 1.1 €/kg (22%) lower than for unsubsidised new plants. For example, a targeted production of 14 TWh of green hydrogen in Germany would lead to a reduction of the production costs by 1.1 €/kg, and thus to a cost saving of approx. 460 million € per year.
- **Restriction to new plants will harm the market ramp-up:** Besides the pure cost advantages, allowing existing plants would also be advantageous for increasing availability. In the next few years, there will be sufficient existing unsubsidised renewable plants for the market ramp-up of hydrogen. Further, a restriction to new plants does not seem practicable due to the long approval periods for the construction of renewable plants. For example, the project duration for the construction of a wind power plant can be four to five years. Such long lead times would jeopardise the timely market ramp-up of the hydrogen economy.
- **A restriction to surplus electricity is not a practicable alternative**: A consideration of the feed-in management measures further shows that surplus electricity in itself is currently not available in sufficient quantities to achieve the goals of the hydrogen strategy. Even if surplus electricity quantities were sufficiently available and could be used free of charge, the low utilisation of the electrolysers would lead to high production costs due to the restriction of operation to times with surplus electricity. The use of surplus electricity should therefore only be able to be used as one of several supply sources.

Figure 2 Hydrogen production costs for existing and new plants in different accounting periods (mixed profile)



Source: Frontier Economics

Note: Calculation based on power prices and profiles in 2019.

Temporal correlation – Longer accounting periods reduce hydrogen production costs

We make the following findings regarding the temporal correlation between electricity production from renewable energies and the production of green hydrogen:

- **A less strict temporal correlation between electricity production and its use allows for an improved use of electrolysers and reduces green hydrogen production costs**: If accounting periods are longer (e.g. monthly or daily) electrolysers with a lower capacity or a higher capacity utilisation, respectively, can be operated. This leads to a reduction in average production costs per unit of green hydrogen produced. The production costs for green hydrogen with electricity purchased from PV systems are approx. 2 €/kg (38%) lower than it would be the case with a strict temporal correlation (quarter-hourly to daily). For electricity purchased from wind power stations, the cost-saving effect amounts to 0.4 €/kg (-11%) for a monthly accounting period compared to a quarter-hourly. Expanding the accounting period for wind power plants up to one year would allow for an even greater savings potential of around 0.7 €/kg (20%) compared to a quarter hourly accounting period. Depending on the purchased portfolio, expanding the temporal correlation to one day would already contribute to a significant decline in production costs.
- **Hydrogen production is flexible even if it is not coupled to renewable production**: Since under our assumptions both power generation from renewable energies and hydrogen production are grid-connected, opportunity

costs for electricity production and consumption are related to the electricity wholesale market. This means that in times of high electricity prices, electrolysers will be keen to sell their contracted renewable electricity on the wholesale market. Consequently, price signals from the wholesale market have a direct influence on the electrolysers' decisions. This is relevant to the system efficiency of hydrogen production. An overall correlation between renewable electricity production and hydrogen production does not require a high temporal correlation. Further, incentives for a system efficient operation of hydrogen production will not require an additional cap on the levy exemption for a fixed number of full-load hours.

- **Additionality of electricity production for hydrogen production is also achieved if accounting periods are longer:** The additionality of electricity production for the generation of green hydrogen derives from the requirements on electricity production plants where electricity can be purchased to produce green hydrogen. The accounting period defines the period in which this additionality must be available. This ensures that during the period defined, additional electricity requirements to produce green hydrogen will be available from an additional production of green power.

Geographic correlation – Limited electricity availability would set location incentives but would be difficult to implement

We make the following conclusions about a possible geographic limitation of production sites for renewable energies and for the production of hydrogen:

- **Geographic restrictions prevent the optimisation of the RE portfolio:** This implies additional costs and uncertainty for investors. Consequently, such restrictions would make the market tramp-up of the hydrogen industry more difficult and expansive in many parts of Germany.
- **Location incentives for hydrogen production will be needed in the medium term:** One of the advantages of hydrogen is that it can be used to transport very high quantities of energy and help to avoid a cost-intensive expansion of power transmission grids. Consequently, incentives for electrolysers to choose a site close to the production site, e.g. in the North of Germany, would be sensible. However, it is unclear whether the instrument of locational correlation provided in RED II would be optimal; alternative instruments such as grid bonuses for electrolyser settling in certain regions or a tendering of sites could be more effective. In the short to medium term, however, geographic restrictions would complicate the ramp-up of a hydrogen industry for consumers, at least while there is no long-distance transport grid available for hydrogen.

Therefore, at least in the near term, there is a case for refraining from strict geographic correlation requirements.

Conclusion: Criteria for the establishment of the hydrogen industry should be as broad as possible

Our analysis show that even in absence of any green power criteria, the costs of electricity-based hydrogen in Germany (approx. 2.6 €/kg) will significantly exceed those of grey hydrogen (1-1.5 €/kg) or blue hydrogen (made from natural gas with a CO_2-capture, 2 €/kg) at least in the short to medium term. This already constitutes a considerable challenge for the establishment of a German hydrogen industry even without considering the infrastructure investments needed to set up the hydrogen industry and ensure transmission, distribution and storage and corresponding end uses (e.g. fuel cells).

If green power criteria are applied hydrogen production costs will increase further to at least around 3 €/kg and will increase to 4 – 5 €/kg if the criteria (e.g. quarter-hourly balancing) are applied strictly. Under these conditions it is questionable whether the market ramp-up of green hydrogen can comprise more than just pilot projects. This will be particularly problematic if strict green power criteria are directly or indirectly applied not only to the transport sector, but also to other sectors.

Further, the way that green power criteria are designed has a considerable impact on the availability of renewable energies to produce electricity-based hydrogen. Excluding existing plants completely and thus limiting "additionality" to unsubsidised new plants yet to be built would be critical particularly for two reasons. First, large available potentials in unsubsidised existing plants would remain unexploited. This could lead to these plants leaving the market although they could have been operated for several years if only they had been included in the green energy system. Second, allowing existing plants will be necessary in order to avoid considerable delays in the market ramp-up of the hydrogen industry due to long implementation periods. Lengthy authorisation periods for renewable energy plants will have a braking effect on the ramp-up of the whole hydrogen industry. The more complicated the authorisation procedure for RE plants, the more difficult it will be to get access to new locations. It is uncertain whether and when new wind offshore plants can be used to produce hydrogen, particularly given that offshore locations can only be made accessible by means of a tendering system under the energy law framework.

The same applies to the geographical correlation. If the requirements are too strict, this might have an inhibiting effect on the hydrogen industry, at least in the early stages. Geographical restrictions of hydrogen production might prevent the RE plant portfolios of hydrogen providers from being optimised, depending on the design of these restrictions. This could lead to additional costs and cause further uncertainty among investors.

Consequently, we would recommend setting the criteria for the purchasing of green energy in Germany as broadly as possible in order to support the market ramp-up of hydrogen in Germany. There are several options available to ensure a smooth entry.

First, the requirements on green electricity criteria could initially only be applied to part of the electricity the electrolysers use. The Federal Ministry for the Environment (BMU) for example proposes that initially only 60% of electricity purchases must be "additional" in the sense of RED II.[1] And in its proposal for the implementation of the EEG regulation, the Federal Ministry for Economic Affairs

[1] BMU (2020) – Herstellung von strombasierten Kraftstoffen – Vorschlag für Kriterien für die Anrechnung als vollständig erneuerbaren Strom beim Strombezug im Rahmen der Umsetzung der Erneuerbaren Energien Richtlinie II – as of 22/06/2020, p.8.

(BMWi) envisages a gradual increase in green electricity procurement from 10% by 2024 to 40% from 2026 onwards.[2]

Second, initially loose green power criteria could be gradually tightened over time as the costs of hydrogen production decrease due to more efficient production processes and technical progress.

However, the suitability of the green power criteria is questionable given that the share of renewable energies in the electricity mix is significantly increasing. Like the regulations for e-mobility, it could be possible to refrain from specific green power criteria. In this case, the green energy characteristics would – in contrast to today's approach – be treated equally across all defossilisation technologies.

[2] BMWi (2021) – Stakeholder-Dialog EEG-Verordnung grüner Wasserstoff, 18/03/2021, p. 8.

www.frontier-economics.com