

Hydrogen From Electricity – Setting Sustainability Standards to Meet Innovation, Deployment and Climate Action

July 2020

Renewable Hydrogen Recommendations

Renewable Hydrogen / Low carbon Hydrogen / Clean Hydrogen that is produced from electricity requires Sustainability Criteria to deliver emissions reductions, increase renewable deployment and to prevent greenwashing of fossil fuels.

- **Alignment with Sustainability Taxonomy.**
 - 100g CO₂/KWh threshold electricity consumption ensures that low carbon electricity is used to produce low carbon hydrogen.
- **Effective tracking and logging of electricity used in the production of low carbon hydrogen.** As in the REDII “methodology should ensure that there is a temporal and geographical correlation between the electricity production unit with which the producer has a bilateral renewables power purchase agreement and the fuel production.”
 - A Temporal Dimension. When is the low carbon / renewable electricity generated. Knowing the timing of generation allows for the hydrogen production unit to follow in real time real world low carbon generation. This means the hydrogen electrolysis unit only consumes low carbon electricity and thus produces low carbon hydrogen.
 - A Geographical Dimension. Is the electricity generation connected in a real way, such as via a shared electricity network, to the hydrogen production unit.

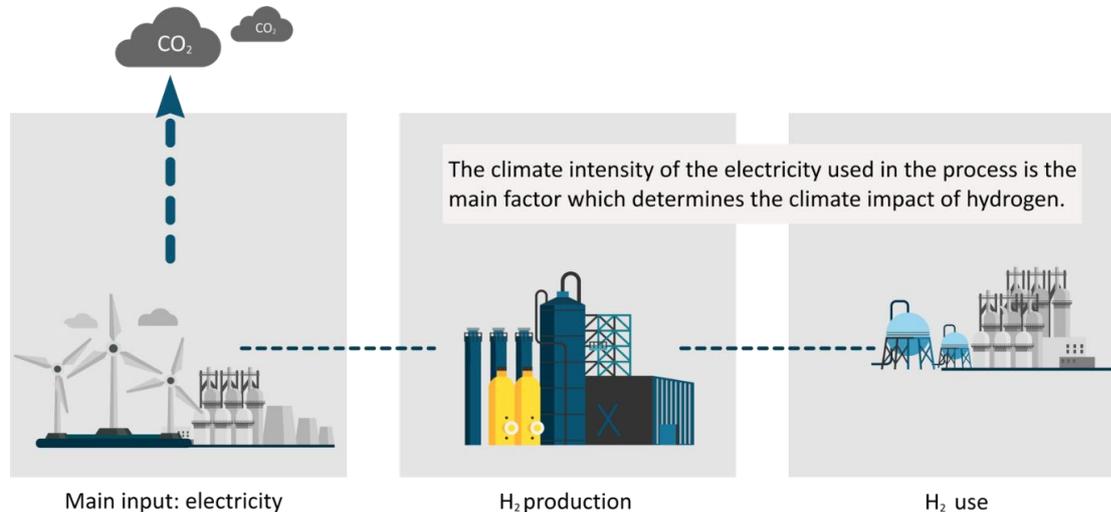
Hydrogen from electricity or electricity for Hydrogen? – Setting Standards to meet sustainable Innovation, Deployment and Climate Action.

Hydrogen production from electricity has moved centre stage in the decarbonisation and renewal of Europe economy and society. Hydrogen is widely seen as foundational in the decarbonisation of industry, transport and the electricity supply system. All of these diverse sectors to a greater or lesser degree now share a common dependence on the delivery of low carbon hydrogen to in-turn decarbonise. A failure to supply this hydrogen in a low carbon way would place the decarbonisation of much of the European economy at risk.

Ongoing delegated Acts for the Renewable Energy Directive along with the incorporation of the Clean Hydrogen Alliance and European hydrogen strategy mean that the coming weeks will be crucial in setting a decades course on the climate criteria for the production of hydrogen. Sustainability criteria for hydrogen production from electricity will need to reflect the requirement for innovation and deployment while safeguarding real world emissions reduction and carbon accounting.

The carbon intensity of electricity used to manufacture electrolysis hydrogen is the determining factor of the carbon intensity of hydrogen produced. **High carbon electricity produces high carbon hydrogen.** The EU sustainable taxonomy sets a benchmark of 100gCO₂/KWh for hydrogen production – this ensures hydrogen has a lower carbon footprint than fossil gas¹ and that it complements, rather than contradicts, the EU Green Deal and in particular works alongside the financial shift required to make it a reality.

Electric vehicles, electric heat pump systems and other direct electrification process that are characterised by very high overall efficiency will in nearly all European cases reduce overall emissions (and fossil fuel use) regardless of the carbon intensity of electricity used. In contrast hydrogen electrolysis has the potential to exacerbate emissions from a carbon intensive electricity sources, creating increased demand for coal and natural gas electricity that multiply overall emissions.



¹ The sustainable taxonomy regards hydrogen manufactured with electricity of 100gCO₂/KWh to be taxonomy compliant. A hydrogen electrolysis operating at 80% efficiency would result in a carbon intensity of $100/0.8 = 138\text{gCO}_2/\text{KWh}^{\text{thermal}}$, this compares favourably with natural gas combustion at $\sim 204\text{gCO}_2/\text{KWh}^{\text{thermal}}$. JRC (2017). Definition of input data to assess GHG default emissions from biofuels in EU legislation https://ec.europa.eu/energy/sites/ener/files/documents/default_values_biofuels_main_report1_online.pdf

Innovation Fund: Anticipating Net Zero Accounting in a Carbon Intensive Decade

The Innovation Fund (IF) expert group of the European Commission (DG Clima) has recently produced a detailed methodology for assessing the emissions reduction from innovative climate projects and technologies seeking European support². The final emissions reduction methodology agreed in this format saw the requirement for the use of real-world current data removed. Instead of the most accurate current data, the assessment of emissions reduction would be based on anticipated electricity carbon intensity in 2050, assumed to be near zero³. The Innovation Fund emissions reduction methodology can still claim to be based on a full Life Cycle Assessment (LCA), although now the data input come from the future.

Ultimately this allows any electricity intensive project proposal (such as hydrogen electrolysis or e-fuels) to exclude emissions from electricity consumption⁴. The use of coal, gas or renewable electricity would all be treated as zero emissions energy sources.

Rational for exclusion of electricity emissions

It is required that projects funded by the Innovation Fund reduce emissions by ~75%⁵. The regions and Member States that have today sufficiently low carbon electricity to produce low carbon hydrogen to meet this benchmark is small. Countries with carbon intensive electricity generation including Germany and Poland would not have been eligible to receive IF funding for hydrogen electrolysis demonstrations. The removal of the need for real world data when calculating the emissions intensity has removed any geographic restrictions where hydrogen or e-fuels projects could be developed and supported by an Innovation Fund.

Advantages for deployment and testing

- ✓ Removal of sustainability criteria allow Innovation Fund to focus on technology development and demonstration, not economy scale deployment
- ✓ Projects not required to reduce emissions allows for all Member States to take part in development, testing and innovation of critical technologies (e.g. hydrogen electrolysis)
- ✓ No geographic restriction on demonstrations due to low carbon electricity availability allows for a greater proportion of the Innovation Fund to be spent on technologies dependent on future availability of clean electricity

Risks for climate action and potential for green washing fossil fuels

- ✗ Hydrogen produced with high carbon electricity can be reported as 'low carbon hydrogen'
- ✗ The Innovation Fund emissions avoidance modalities are also the basis for emissions accounting the REDII Delegated Act(s) on electricity fuels. Direct replication of the IF would result in carbon intensity of electricity to be removed from REDII – effectively removing sustainability criteria from hydrogen and e-fuels production
- ✗ The IF is a significant funding source, alignment of standards and account creates a big potential for consequentiality of the IF accounting to be repeated in other EU programs
- ✗ The ability in the IF to use "futuristic" data in a Life Cycle Assessment is short sighted. A distinct and clear dispensation for innovative projects would be more rigorous

² Annex B: Methodology for calculation of GHG emission avoidance

³ Net grid electricity consumed is "Expected 2050 electricity mix"

⁴ This can also be described as the exclusion of much of "Scope 2 Emissions". Scope 2 emissions cover indirect GHG emissions from consumption of purchased electricity, heat or steam.

⁵ Innovation Fund Expert Group meeting 18 December 2019 https://ec.europa.eu/clima/sites/clima/files/innovation-fund/ifeg18dec_en.pdf

Innovation Fund Recommendation:

Given the decision to disregard any electricity emissions for industrial projects applying for the Innovation fund, it should be made clear that this is an exception which should not be taken up in other legislative acts, such as the Renewable Energy Directive and its delegated acts.

Assessing the Carbon Intensity of Hydrogen via Electrolysis

Low carbon electricity can be used to generate low carbon hydrogen. Conversely the use of carbon intensive sources of electricity can increase emissions and fossil fuel use in the electricity system.

The EU sustainable taxonomy sets a benchmark of 100gCO₂/KWh for hydrogen production – this ensures hydrogen has a lower carbon footprint than fossil gas.

Producing hydrogen from coal electricity would increase emissions more than 3x time over today's polluting hydrogen production via SMR.

Hydrogen produced using the average electricity grid in Germany (440 gCO₂/KWh)⁶ would increase emission 1.7x times over current hydrogen production or 2.7x times over direct natural gas use in process heating.

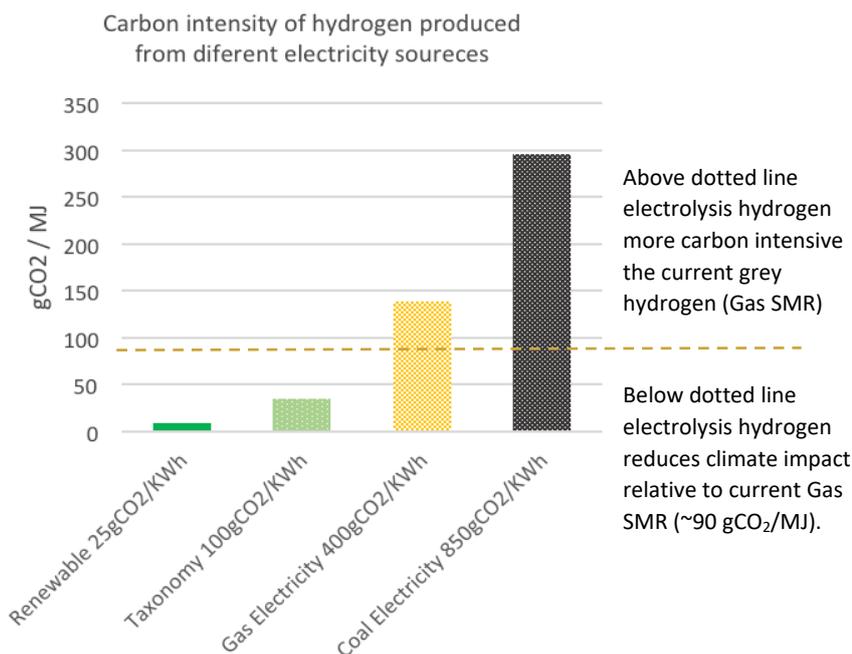


Figure 1 Comparing the carbon intensity of hydrogen produced (gCO₂/MJ) from different electricity generation sources (gCO₂/KWh). H₂ electrolysis @ 80% efficiency¹

Electricity production in Germany is carbon intensive due to the significant contribution from coal and gas. These generation sources are planned to remain with a coal phase out planned for the late 2030s.⁷

⁶ EEA 2018 CO₂ emissions intensity [https://www.eea.europa.eu/data-and-maps/daviz/co2-emission-intensity-5#tab-googlechartid_chart_11_filters=%7B%22rowFilters%22%3A%7B%7D%3B%22columnFilters%22%3A%7B%22pre_config_ugeo%22%3A%5B%22European%20Union%20\(current%20composition\)%22%5D%7D%7D](https://www.eea.europa.eu/data-and-maps/daviz/co2-emission-intensity-5#tab-googlechartid_chart_11_filters=%7B%22rowFilters%22%3A%7B%7D%3B%22columnFilters%22%3A%7B%22pre_config_ugeo%22%3A%5B%22European%20Union%20(current%20composition)%22%5D%7D%7D)

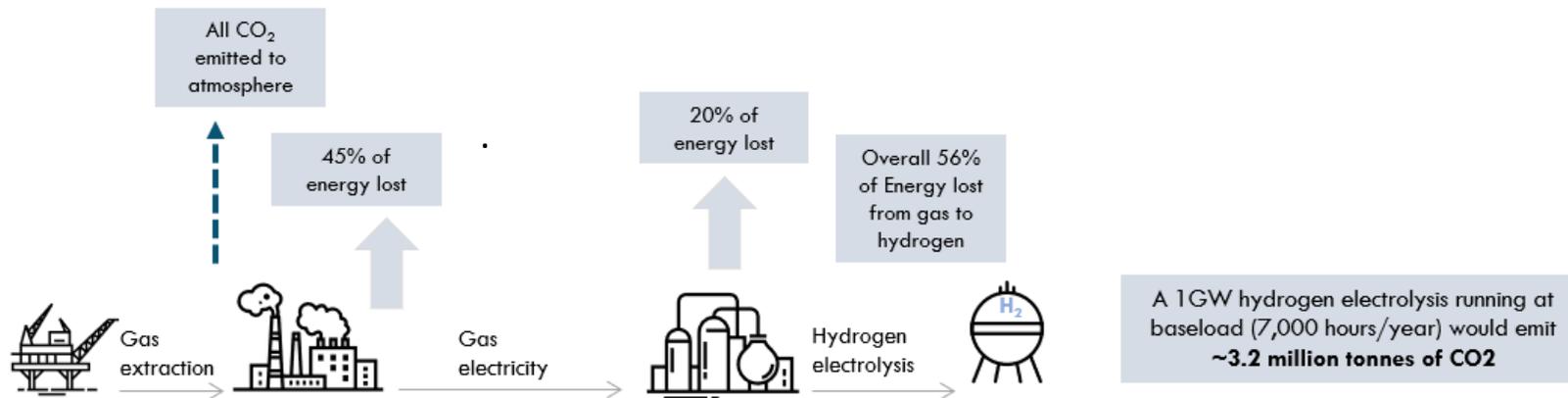
In contrast hydrogen produced in a Member State with low carbon electricity would produce a low carbon hydrogen to replace fossil fuels. The Swedish grid has very low emissions (~13.3 gCO₂/KWh)^{Error! Bookmark not defined.}. Thus, hydrogen produced in Sweden cuts emissions by 90% when compared to fossil hydrogen from SMR.

Comparing the climate and operational implication of hydrogen produced with any electricity and hydrogen produced solely from renewable low carbon electricity	Any Electricity Hydrogen Electricity emissions are ignored: <ul style="list-style-type: none"> > Replaced with future data as in the Innovation Fund. > Excluded under the rationale “Electricity emissions are dealt with by the ETS” so should not count towards hydrogen carbon intensity Result in the use of any electricity, in any region at any time to produce hydrogen labelled as “zero carbon”	Renewable Hydrogen Electricity emissions are counted as the core metric in assessing the sustainability of hydrogen production from electricity Hydrogen production follows local actual renewable generation to produce zero carbon hydrogen
Climate Impact & CO₂ Emissions As in fig 1 producing hydrogen with coal or gas increases emissions above that of the fossil equivalent electrolysis hydrogen is to replace.	<ul style="list-style-type: none"> ✗ The use of carbon intensive electricity will result in a significant increase in emissions ✗ Potential for emission increase to be unreported 	<ul style="list-style-type: none"> ✓ Hydrogen produced from renewable electricity is low carbon
Geographical deployment	<ul style="list-style-type: none"> ✓ No geographical restriction beyond electricity grid connection 	<ul style="list-style-type: none"> ✗ In areas where renewable generation is available or where grids electricity is low carbon
Time & scale of deployment	<ul style="list-style-type: none"> ✓ Electrolysis can be deployed sooner and at a larger scale if not dependent on low carbon electricity 	<ul style="list-style-type: none"> ✗ Becomes available as renewable generation is constructed. Limited scale of deployment in medium term.
Utilisation of electrolysis Capital intensive units (such as a hydrogen electrolysis unit) can report lower overall cost if operated at higher utilisation (operated year round or as baseload demand)	<ul style="list-style-type: none"> ✓ With a grid connection and the right to use any electricity a hydrogen electrolysis unit would have the option to run year round. 	<ul style="list-style-type: none"> ✗ The hydrogen unit would operate intermittently, following solar and wind generation. This would limit overall utilisation
Operational flexibility & electricity supply system. Additional electrical demand has the potential increase flexibility of electricity supply system (smart grid) or to reduce flexibility	<ul style="list-style-type: none"> ✗ Depending on the structure of the support mechanism, hydrogen units would operate at high utilisation – adding a baseload demand to the grid they are connected to. This would reduce flexibility and create a greater need for dispatchable baseload electricity generation 	<ul style="list-style-type: none"> ✓ Hydrogen units dependent on renewables would operate in response to renewable generation. In this way hydrogen units would add flexibility to the grid – absorbing energy in times of high renewable generation.
Fossil fuel extraction and use	<ul style="list-style-type: none"> ✗ Full load hours for hydrogen production will increase electricity demand. ✗ If hydrogen generated from fossil electricity is branded as “low carbon” then this would greenwash fossil electricity production. 	<ul style="list-style-type: none"> ✓ No fossil energy would be used for electrolysis hydrogen

⁷ Spelling out the coal exit – Germany’s phase-out plan, Clean Energy Wire 2020. <https://www.cleanenergywire.org/factsheets/spelling-out-coal-phase-out-germanys-exit-law-draft>

EXAMPLES: Projects that would be considered “low carbon” if ‘Any Electricity Hydrogen’ is the European standard

Example 1: Fossil Electricity (gas) to Hydrogen Electrolysis



Electricity Emissions accounted

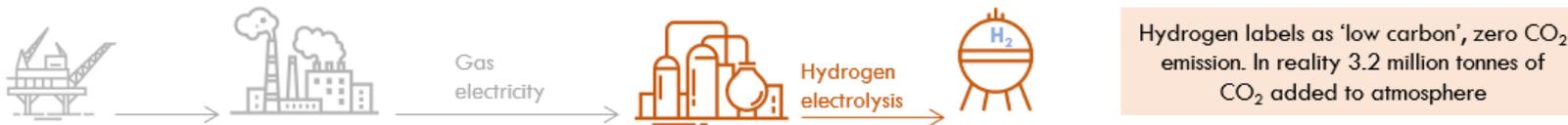
Natural Gas emits **~57 g CO₂** per Mega Joule

Natural Gas electricity production at **~55% efficiency**

Combustion of natural gas to produce electricity emits CO₂ to the atmosphere. These emissions are part of the carbon intensity of hydrogen production. Gas electricity = **370g CO₂/KWh**

Hydrogen production from gas electricity emits **129 g CO₂** per Mega Joule of hydrogen

With more than 1/2 of the energy lost, the hydrogen produced has an emissions intensity greater than “grey hydrogen” and **2 times** that of fossil gas. Gas electricity to hydrogen is more carbon intensive and less efficient than current direct gas to hydrogen.



Electricity Emissions not accounted

Innovation Fund does not account for electricity emissions (scope 2 emissions). Replicating this methodology in REDII would lead to wild greenwashing

Emission can be treated as if it were “2050” and 100% renewable. In practice this means gas electricity can be branded as renewal and clean. Gas Electricity now = **370g CO₂/KWh** **0g CO₂/KWh**

Hydrogen production from gas electricity emits **0 g CO₂** per Mega Joule of hydrogen

Gas electricity can now be used to create “clean” hydrogen. Carbon intensive gas electricity can be treated as if it was renewable. Electricity emissions no longer counted. Investment in extraction and burning of fossil gas can now produce “low” carbon subsidised hydrogen

Example 2: Coal Electricity + Coal CO₂ to 'Low Carbon E-fuel'

Producing synthetic fuels from captured CO₂ with hydrogen is presented as another pathway to decarbonize energy carriers and utilize hydrogen. Using CO₂ from industrial emitters, such as cement and steel but also coal power plants, is cheaper than direct air capture and therefore preferred from a commercial standpoint. Hydrogen from electrolysis is combined with this CO₂ to produce fuel or gas, which is then combusted, releasing the initially captured CO₂ from the industrial site, for example through the exhaust in a Diesel car.

In the example of the ALIGN CCUS demonstration plant for producing synthetic fuel (DME) in North Rhine Westphalia (NRW), CO₂ is captured from RWE's Niederaussem lignite-fired power plant. Electrolysis using grid electricity delivers the hydrogen to inter alia produce fuel for cars.⁸

When electricity emissions are not counted **Coal to E-fuels** plants would be accounted as 'low carbon' despite the use of coal and the addition of CO₂ to the atmosphere. RWE would therefore be remunerated both per 1kWh of coal electricity supplied to produce the hydrogen, and the 756g of coal CO₂ captured to be added to the hydrogen to synthesis the e-fuel. On a side note, since the electrolyser runs on grid electricity and is in close proximity to the coal power plant, it is likely that much of the coal generated electricity is physically used to produce 'low carbon' hydrogen and e-fuel. All the CO₂ in the e-fuel will be added to the atmosphere on combustion.

The emissions intensity of the e-fuel produced would be far higher than that of traditional and already damaging fossil fuels. The overall carbon intensity would be increased 2x or 3x times depending on the average mix of electricity used. If the electricity is not accounted for these coal consuming carbon intensive fuels would be labelled as 'low carbon'.⁹

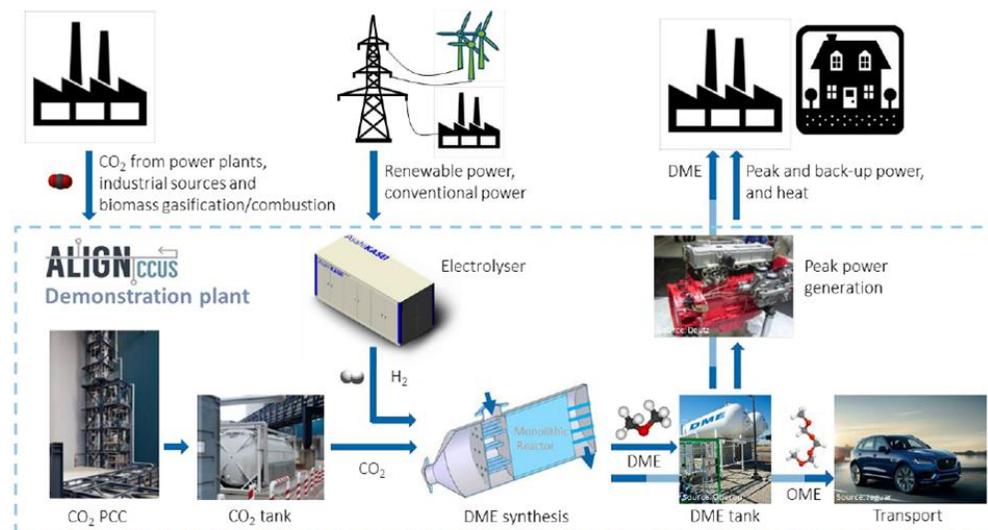


Figure 2 Diagram of the Coal to-Fuels pilot plant at Niederaussem lignite-fired power plant

⁸ Demonstrating the CCU-Chain and Sector Coupling as Part of ALIGN-CCUS - Dimethyl Ether from CO₂ as Chemical Energy Storage, Fuel and Feedstock for Industries https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3366051

⁹ Gabrielli, Gazzani, Mazzotti (2020) The Role of Carbon Capture and Utilization, Carbon Capture and Storage, and Biomass to Enable a Net-Zero-CO₂ Emissions Chemical Industry <https://pubs.acs.org/doi/10.1021/acs.iecr.9b06579>

Sustainability criteria for Clean Hydrogen: enable deployment and safeguard climate investment

Europe needs a functional sustainability criteria for low carbon electricity hydrogen that marries immediate innovation and deployment while safe guarding climate criteria. The means to an end matter and in the light of the climate emergency, it is more important than ever that the pathways to a hydrogen powered future are designed in line with the low carbon intensity criteria of the EU Green Deal.

The Clean Hydrogen Alliance needs to live up to its name and therefore be focusing on clean hydrogen, as well as aiming to stand the test of time by being a true alliance for innovation. The goal should be to safe guard the renewable and green credentials of electrolysis hydrogen today and in 2050. When designing criteria we must be cognisant of the difficult lessons learned from initial sustainability criteria of biofuels. Foremost that amending and improving sustainability criteria to a market once in place is extremely difficult, slow and populated with entrenched stakeholders that will defend low or failing sustainability criteria.

There would be nothing more disheartening, that after all this effort to deploy hydrogen to fight the climate crisis that Europe omit the criteria for hydrogen to be produced in a climate effective manner. Making a positive climate effect a non-requirement for climate action seems fundamentally perverse.

Direction from the Commission is needed now on setting a path for hydrogen sustainability criteria as multiple hydrogen policies including delegated acts linked to “Renewable Fuels of Non-Biological Origin” are underway. These will define how and when “low carbon” hydrogen and e-fuels from electricity will be produced and eligible for subsidy.

Assessing and tracing electricity used in hydrogen production

The key criteria for producing low carbon hydrogen from electricity is an effective way to track and account for the electricity used. Accurately doing so will allow the widest deployment of low carbon hydrogen while preserving sustainability criteria.

To accurately reflect the real world operation of electricity generation a certification system for the electricity used in hydrogen production must at a minimum include:

- > **A Temporal Dimension** (when is the low carbon / renewable electricity generated)
 - Knowing the timing of generation allows for the hydrogen production unit to follow in real time real world low carbon generation. This means the hydrogen electrolysis unit only consumes low carbon electricity and thus produces low carbon hydrogen, rather than increase base-load and thereby fossil fuel electricity.
- > **A Geographical Dimension.** Is the electricity generation connected in some way, such as via a shared electricity network, to the hydrogen production unit

The ability to accurately assess the location and timing of production of low carbon electricity allows for low carbon hydrogen to be produced in many more settings:

- ✓ **Allows for low carbon hydrogen electrolysis units to be connected to the electricity grid,** therefore increasing and geographically liberating deployment. Carbon intensive electricity grids such as that in Germany would be able to host low carbon hydrogen production. Variable renewable generation located elsewhere on the grid or physically connected grids could be accurately reflected in the operation of the hydrogen facility.
- ✗ **Prevents increased use of fossil electricity generation.** As the time of the low carbon generation is known hydrogen units will operate flexibly in response to available low carbon generation. Units will not operate at baseload requiring increased dispatchable fossil generation to meet electricity needs. This in turn prevents subsidies to hydrogen production indirectly subsidising increased fossil fuel use in electricity production.

- ✓ **Provides a high degree of certainty that low carbon hydrogen is indeed low carbon** while maintaining deployment flexibility by reflecting the real world operational nature of electricity generation and hydrogen production.
- ✓ **Delivers a strong signal for new Renewable Electricity generation to accompany hydrogen deployment.**
- ✓ The terms of the **delegated act** for ‘Renewable Fuels of Non-Biological Origin’ **already includes a functional reference to the need to temporal and geographical correlation** between the electricity production and use. The Commission should maintain and expand upon this as a standard piece of the sustainability criteria for low carbon hydrogen.

Electricity certification by Guarantee Of Origin (GO) is far from sufficient

The use of the existing guarantee of origin (GO) system would allow grid connection, the use of any electricity and around the clock operation of a hydrogen electrolysis unit. However, all of the significant draw back of “Any Electricity Hydrogen” introduced above would remain or be exacerbated. Namely an increase in both emissions and fossil fuel use while reducing the need for addition renewable capacity.

- ✗ Guarantees of origin do not provide sufficient information on the timing of low carbon generation. Guarantees of origin would allow hydrogen production to run as a baseload electricity consumer regardless of actual electricity generation and carbon content of electricity.
- ✗ Guarantees of origin do not reflect real world electricity transmission capabilities. GOs can be traded across Europe even if no physical connection exists. This again divorces the hydrogen production plant from the real world availability of low carbon electricity.
- ✗ Due to the lack of temporal and geographic constraints, GOs provide an exceptionally weak signal for the construction of additional renewable generation and grid strengthening to meet increased electricity demand from hydrogen production.
- ✗ Very affordable greenwashing of fossil electricity to ‘zero carbon’ electricity.
 - A natural gas power plant emits ~0.37 tonnes of CO₂ per MWh of electricity generation, with an ETS cost of €9. Rebranding this fossil gas electricity as ‘zero carbon’ electricity with a GO would add as little as €0.20 (current price) to a historic high of €2 (2018).
- ✗ Example 1 and 2 above would be possible with a GO system. Low priced GOs used to ‘clean’ fossil electricity allowing ‘low carbon’ hydrogen and e-fuels to be production with fossil gas and coal. ^{10 11 12} Error! Bookmark not defined.

¹⁰ NREL Life Cycle Assessment of a Natural Gas Combined-Cycle Power Generation System <https://www.nrel.gov/docs/fy00osti/27715.pdf>

¹¹ ETS EUA trading at €25 on 02/07/2020 <https://markets.businessinsider.com/commodities/co2-european-emission-allowances>

¹² In 2018, "standard GOs from Nordic hydropower, an industry benchmark, traded at a record high of EUR 2/MWh, while they are currently languishing at around EUR 0.20/MWh" <https://www.greenpowerhub.com/portuguese-tso-joins-european-go-market-with-13-twh-supply/>

Recommendations for the Clean Hydrogen Alliance

Renewable Hydrogen / Low carbon Hydrogen / Clean Hydrogen that is produced from electricity requires Sustainability Criteria to deliver emissions reductions, increase renewable deployment and to prevent greenwashing of fossil fuels.

- **Alignment with Sustainability Taxonomy.**
 - 100g CO₂/KWh threshold electricity consumption ensures that low carbon electricity is used to produce low carbon hydrogen and that financial flows support innovation in line with the principles of the EU Green Deal.
- **Correct tracking and logging of electricity used in the production of low carbon hydrogen.**

As in the REDII “methodology should ensure that there is a temporal and geographical correlation between the electricity production unit with which the producer has a bilateral renewables power purchase agreement and the fuel production.”

 - A Temporal Dimension (when is the low carbon / renewable electricity generated). Knowing the timing of generation allows for the hydrogen production unit to follow in real time real world low carbon generation. This means the hydrogen electrolysis unit only consumes low carbon electricity and thus produces low carbon hydrogen.
 - A Geographical Dimension (is the electricity generation connected in some way, such as via a shared electricity network, to the hydrogen production unit)

Hydrogen deployment should not overshadow or be delivered at the expense of direct electrification. Options such as electric vehicles, heat pumps, water heaters and smart grids offer high efficiency use of electricity, are efficient at converting most electricity sources into immediate emission reductions and can add flexibility to electricity consumption. The next decade is of crucial importance in whether or not the world stands a chance in meeting the scenarios of the Paris Agreement. A risk minimising strategy is best supported by sustainability criteria across all innovations. Furthermore, this would fill the gap that was identified as a priority by the European Commission itself in its renewable sources directive from December 2018:

“The Commission should develop, by means of delegated acts, a reliable Union methodology to be applied where such electricity is taken from the grid. **That methodology should ensure that there is a temporal and geographical correlation between the electricity production unit with which the producer has a bilateral renewables power purchase agreement and the fuel production.**”(90)¹

A hydrogen powered future needs to be a revolution of our energy system, not an evolution of the fossil gas industry.



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