Response to the EU Hydrogen Strategy

Low- and zero-carbon fuels (hydrogen, ammonia, methane and other hydrocarbons) will be a valuable and scarce resource in the future due to their high resource requirements. In the case of synthetic liquid and gaseous fuels such as hydrogen, the energy-intensive production process and the electricity resources used for it will determine their climate impact. [i] **Since hydrogen will require significant resources to produce, the environmental criteria for its production should be determined prior to their large-scale deployment.** Regardless of how the low carbon hydrogen is produced, a full lifecycle assessment must take into account all indirect emissions caused by or associated to its production.

Hydrogen production

95% of hydrogen used today is produced from fossil fuels, predominantly via fossil methane steam reforming (SMR). With the CO_2 coming from the process vented into the atmosphere, the production of fossil hydrogen contributes to an overall increase of emissions and is not compatible with European climate goals[ii,iii].

Hydrogen from SMR + carbon capture and storage (CCS)

Prior to the large scale deployment of renewable electrolytic hydrogen, the production of fossil hydrogen and the continued use of fossil gas should not be left unmitigated. 71-92% of the emissions caused directly by steam methane reforming can be mitigated through carbon capture and storage. Low carbon hydrogen from steam methane reforming is already produced in combination with CO_2 storage in Alberta, Canada[iv].

Coupling hydrogen CCS projects with increased RES deployment and the development of more efficient, large-scale electrolysers could be a way forward for hydrogen production. However, when accounting for the climate impact of such hydrogen production processes, the emissions of the entire SMR+CCS chain should be taken into account, including fugitive methane emissions during extraction, transport and storage of the gas[v]. Just as hydrogen produced with fossil grid electricity can have higher emissions than its fossil counterpart, indirect emissions and gas leakage in the SMR+CCS chain can influence the climate benefit of the hydrogen produced.

Electrolytic hydrogen

For hydrogen produced via electrolysis, the electricity going into the process determines the GHG intensity of the hydrogen. Identifying break-even points compared to other fossil fuels would help identify the hydrogen which is genuinely renewable and compatible with climate goals. For instance, the UCL Energy institute in the UK requires deeply decarbonised electricity of 50 g CO_2/KWh to be used by 2050 [vi] when defining green hydrogen from electrolysis.

The following table summarises the thresholds relevant for hydrogen from electrolysis. In other words, the table estimates how ‘low-carbon’ the electricity input should be (electricity carbon intensity) to provide the same ‘energy service’ (carbon intensity/energy provided) as a given fossil fuel (e.g. natural gas):

Technology	Electricity Carbon Intensity production	Carbon intensity / energy provided
Comparison of hydrogen carbon footprint with low- and high-carbon electricity		
Hydrogen produced via electrolysis, low carbon electricity	~100 gCO_2/kWh	~138 $gCO_2/kWh_{thermal}$
Hydrogen produced via electrolysis, high carbon electricity	~440 gCO_2/kWh	~551 $gCO_2/kWh_{thermal}$
Comparison with hydrogen from natural gas		
Hydrogen electrolysis (break-even)	~260 gCO_2/kWh	~326 $gCO_2/kWh_{thermal}$
Grey hydrogen (from fossil natural gas)	n/a	~328 $gCO_2/kWh_{thermal}$
Comparison with natural gas		
Hydrogen from electrolysis (break-even)	~149 gCO_2/kWh	~204 $gCO_2/kWh_{thermal}$
Natural gas	n/a	~204 gCO2/$kWh_{thermal}$

Table 1: Climate footprint of hydrogen from electrolysis, compared to fossil hydrogen and natural gas.

Compared to natural gas, the green hydrogen will provide the same energy service at the same carbon intensity when produced in a low-carbon grid emitting 149gCO_2/KWh.

The use of dynamic and declining thresholds for carbon intensity, such as the 100gCO_{2eq}/kWh (to 0gCO_{2eq}/kWh by 2050) by the Technical Expert Group (TEG) on Sustainable Finance can ensure the sustainability of low-carbon hydrogen. Adding similar thresholds both to the Smart Sector Integration Roadmap and the EU Hydrogen Strategy would ensure that fuels produced with renewable energy sources comply with the climate goals of the EU.

While deployment at scale is needed to drive prices down and improve electrolysers, large scale deployment of hydrogen production at this point in time could cause a net increase in emissions due to the emission intensity of electricity grids in Europe. In order to avoid this damaging effect and prevent competition with direct use of RES, the production of hydrogen should be amped up in parallel to the deployment of additional renewable electricity (according to specific thresholds in gCO_{2eq}/kWh).

Biogenic hydrogen

Hydrogen can also be produced by the thermal treatment (gasification) or decomposition (anaerobic digestion) of biomass[vii]. Coupled with CCS and sustainable biomass use (including potential land use change impacts), this process can potentially result in carbon removal[viii]. However, the potential of biogenic hydrogen is limited due to the limited availability of sustainable biomass, low-process efficiencies for anaerobic digestion and high energy requirements for gasification[1]. If the production of hydrogen from biomass takes place, the biomass carbon footprint and the additional energy use need to be taken into account within the GHG accounting methodology.

Recommendations

For any hydrogen production process, it is important to consider the entire production process and all inputs to evaluate the climate impact of the H_2. Setting thresholds and climate criteria for hydrogen production will be crucial to stimulate the development of truly low-carbon fuels. When produced in accordance with robust environmental standards, different hydrogen sources can aid co-developing transport infrastructure, supplying the same market and growing the share of hydrogen as a clean energy source.

- When calculating the emissions of hydrogen from electrolysis, the following emissions should be taken into account:
  - the **carbon intensity of the electricity used** to produce the fuel, **in gCO_2/kWh of respective national grid (unless directly connected with RES)**.
- Using breakeven points to define truly low-carbon hydrogen could be a way to strengthen current prerequisites for the production of these fuels in the EU Hydrogen Strategy:
    - **less than ~149gCO_2/kWh for hydrogen via electrolysis (estimated breakeven point with fossil natural gas)**
    - **less than ~90gCO_2/kWh for synthetic hydrocarbons (estimated breakeven point with fossil counterparts)[2]**
  - the carbon added (if any) fossil (e.g. from industrial point sources) or atmospheric (e.g. CO_2 from direct air capture) + the energy used to capture the carbon
- To ensure the compatibility with climate goals **declining thresholds for carbon intensity (e.g. 100gCO_{2eq}/kWh to 0gCO_{2eq}/kWh by 2050 from the Sustainable Finance Taxonomy) should be used for financial mechanisms supporting low-carbon fuels.**
- **Predictions of the emission factor of the grid in 2030 and 2050 should not be used** to calculate the climate impact of electrolytic hydrogen today.

Hydrogen use and infrastructure

In some sectors, the direct use of electricity will still be preferable due to the energy losses during the production (and subsequent use) of hydrogen. The reflection of this efficiency loss is immediately apparent in sectors where there are alternatives for direct use of electricity.

[1] Other ways of producing hydrogen from hydrocarbons, such as biomass, are being explored but are not addressed in this response due to their low TRL and small scale.
[2] Precise gCO_2/kWh thresholds vary due to the variety of types of fuels and conversion technologies. The estimate in this document is based on assessments from van der Giesen et al. (2014), Falter et al. (2016) and Bringezu and Turnhau (2018).

For instance, such differences are clearly visible in road transport, where a direct electrification method should be preferred:

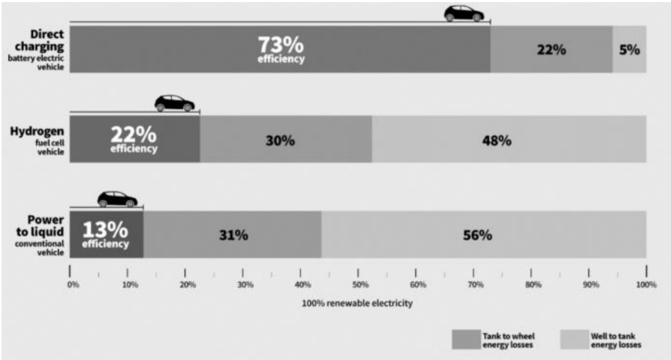

Figure 1: Efficiency of electricity conversion to movement - the difference between electric vehicles, fuel-cell vehicles and synthetic fuel for an ICE (Source: T&E)

In that context, the use of hydrogen and any of its derivatives must be targeted and directed at sectors which do not have direct electrification options for climate change mitigation. The scale of such deployment should be based on the potential for renewable hydrogen production assessed with the threshold and metrics described above.

Production of synthetic hydrocarbons

Synthetic hydrocarbons (also known as e-fuels, renewable fuels of non-biological origin, CO_2 utilisation fuels, CCU fuels) need an even cleaner electricity input to breakeven with their fossil counterparts while providing the same energy service. Creating fuels such as synthetic kerosene and diesel requires lower carbon intensity of the grid (in gCO_2/KWh) due to the additional efficiency loss in the process. For instance, for synthetic aviation fuel, the literature estimates a breakeven of less than 100 g CO_2/KWh with grid electricity. Bringezu and Turnhau (2018) estimate that reaching a break-even point with conventional fossil products requires a minimum 86% renewable power input[ix] (other estimates by Giesen et al.[x] and Falter et al.[xi]).

The carbon source in synthetic hydrocarbons also influences its overall carbon intensity. Synthetic liquid and gaseous fuels still emit CO_2 when they are burned. Hence, the climate effect of synthetic hydrocarbon fuels is not only dependent on the CO_2 intensity of hydrogen production, but also on the energy for capture of the CO_2, the energy lost in chemical synthesis of the fuels and the source of the CO_2 (e.g. atmospheric or fossil origin). If the latter is fossil, it could disincentivise the decarbonisation of other sectors; for instance, if taken from energy intensive industries, the CO_2 of fossil origin would simply be transferred to a different sector and emitted. If installations within the EU ETS would get credit for such a transfer, they would lose incentives to reduce their emissions. Due to such issues, ''the carbon dioxide must originate from the atmosphere or from sustainably produced biomass.''[xii]. Specifying the source of the carbon when talking about synthetic fuels would help in defining the robust environmental criteria for liquid and gaseous synthetic fuels.

The following factors should be taken into consideration to assess the climate impact of such low-carbon fuels derived from clean hydrogen (non-exhaustive list):

Type of 'low carbon' gas/fuel (examples)	Energy and electricity input	Associated indirect emissions or carbon inputs
Hydrogen (SMR+CCS)	Energy use for carbon capture	Upstream methane emissions
Hydrogen (electrolysis)	Electricity used for electrolysis	/
Synthetic gas (CH_4)	Energy use for carbon capture Electricity used for electrolysis	Fossil carbon, Biogenic carbon (+ ILUC impacts), Atmospheric carbon (+ carbon capture energy use)

Recommendations

- Precise and **targeted use of truly low-carbon gaseous and liquid fuels** (meeting criteria above) where direct electrification is not an option or is very difficult:
    - Dedicated infrastructure for hydrogen use in sectors which do not have direct electrification options, e.g. energy intensive industries (ammonia production, direct iron reduction)
- **Dedicated infrastructure for handling and transport of low-carbon fuels** (e.g. hydrogen and ammonia) to avoid blending within the large natural gas grid.
- Investment in hydrogen projects meeting the thresholds for low climate impacts in comparison to their fossil counterparts (e.g. in a region with electricity emission factor of 50gCO_2/kWh)

References

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