Critical Review of the IPHE Working Paper *"Methodology for Determining the GHG emissions associated with the Production of hydrogen"*

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In October 2021, the IPHE (International Partnership for Hydrogen and Fuel Cells in the Economy) published a *Methodology for Determining the Greenhouse Gas Emissions Associated with the Production of Hydrogen,* which in the following is referred to as the “Draft IPHE methodology”[1].

This draft methodology has been prepared by the Hydrogen Production Analysis Task Force of the IPHE. The process was open to all IPHE member countries, but not all of them participated actively in the analysis and in the production of the report. The foreword to the draft methodology clearly states that it “does not necessarily reflect the views of individual IPHE member countries”.

The draft IPHE Methodology represents an important milestone that could potentially be a first step towards the creation of an international standard. On many points, the IPHE Working paper provides a solid basis for a globally shared methodology. However, some important points require reconsideration.

This paper provides a critical review of selected aspects of the draft IPHE methodology. The purpose of this paper is to provide an input to people involved in the consultation process concerning the draft IPHE methodology. The main questions of interest discussed in this paper are:

- Does the methodology miss out on any relevant emissions that should be considered?
- Is the methodology likely to lead to an overestimation or an underestimation of the GHG emissions associated with different H_2 production pathways, or with H_2 production in different countries or regions?
- Are there issues that are not addressed in the methodology, but that should be considered from a sustainability point of view?
- How does the draft IPHE methodology compare with (selected) methodologies implied by certification schemes and strategies adopted in or in course of development in the EU?

[1] https://www.iphe.net/iphe-working-paper-methodology-doc-oct-2021

Summary

- The draft IPHE methodology is likely to lead to a substantial underestimation of the **fugitive methane (CH_4) emissions** and to a difficult comparability between data from different regions. The reasons for the underestimation are
  - (1) the reliance on data from natural gas suppliers about embodied emissions,
  - (2) the lack of requirement for (or even exclusion of) data from satellite monitoring, and
  - (3) the choice of an outdated and too low GWP (Global Warming Potential) factor for methane.

  The draft IPHE methodology relies on data provided by gas suppliers, while the European Methane Strategy aims at creating an independent international body to monitor CH_4 emissions and verify company reporting in this field. Furthermore, the European Methane Strategy gives great importance to satellite and drone based CH_4 emission monitoring, whereas the draft IPHE methodology fails to mention them and could even be interpreted as excluding them.
  Without addressing these points, the IPHE methodology would result in a bias in favor of H_2 production pathways that are more CH_4 emission intensive, essentially SMR[2] with or without CCS.

- Concerning **electricity sourced from the grid**, the draft IPHE methodology can underestimate GHG-emissions attributed to the produced hydrogen compared to the actual effects on the system-wide GHG emissions associated with the additional power demand implied by the production of that hydrogen. Also, comparability between GHG-emissions of hydrogen from different countries is not secured. The reasons are:
  - Additionality of RES-E is not foreseen and can neither be identified nor verified by the method
  - Data of emission factors of grid electricity is not available in all countries and there is no calculation-standard set for the reporting body (grid operator)
  - Using average GHG emission factors of small regions (State or Provinces) can strongly deviate from the real system-wide effects on GHG-emissions.

- In this way, the draft IPHE methodology is not in line with the **European Hydrogen Strategy** and the provisions of the **Renewable Energy Directive** (REDII). The major shortfalls in this respect is that it treats hydrogen production based on additional RES-E generation equal to
  - hydrogen production that is solely based on accounting of existing RES-E (e.g. based on Guarantees of Origin (GOs) or
  - hydrogen that is based on the grid mix of an area which does not reflect the expected system-wide effects on GHG-emissions.

  Criteria on additionality and to a large extent also on geographical and temporal correlation cannot be verified by European public institutions or market participants based on the proposed method. For this purpose, either a separate verification system will have to be used, or the criteria will have to be considered at least as reported information item in the methodology.

- Regarding **CCS**[3], we suggest that the emissions during the injection phase be explicitly mentioned within the methodology.

- The IPHE methodology focuses exclusively on GHG emissions, with a “well-to-gate” system boundary[4]. Due to these two limitations, the **IPHE methodology does not capture all aspects that are relevant from the point of view of the European hydrogen policy making that aims at a sustainable energy supply**.

[2] Steam Methane Reforming
[3] Carbon Capture and Storage
[4] The IPHE methodology indicates that this part will be covered in later documents.

- The “well to gate” system boundary covers all upstream steps up to hydrogen production site, but it excludes the emissions from the subsequent steps (transport, including conversion, reconversion and shipping fuels or losses in pipeline systems). Especially when a (re)conversion takes place, the energy consumption and thus the emissions linked to the (long distance) transport of hydrogen may be substantial. As the EU plans to transport significant amounts of hydrogen and/or derived molecules over long distances, the EU and its Member States should consider also the emissions linked to transport. They are relevant both when comparing different materials and transport options (which may be more or less GHG emission intensive) and when discussing the pros and cons of using hydrogen based energy carriers vis-à-vis alternative carbon neutral options such as energy efficiency, energy sufficiency and direct use of renewables.

- The draft IPHE methodology’s focus on GHG emissions excludes other relevant sustainability criteria, such as the impact of hydrogen production on water resources, land use, biodiversity, air quality, material consumption, toxic or radioactive waste as well as socio-economic issues. These limitations must be considered when assessing the sustainability of hydrogen consumption in comparison with alternatives as well as comparing the sustainability of different pathways of hydrogen production.

1 Risk of a (substantial) underestimation of fugitive methane (CH_4) emissions

Our first analysis suggests that the draft IPHE methodology is likely to lead to a substantial underestimation of the fugitive methane (CH_4) emissions. Such an underestimation would lead to a bias in favor of one pathway of H_2 production: steam methane reforming with or without CCS. Moreover, the quantification of fugitive CH_4 emissions is likely to be subject to different calculations according to country and/or region, which would question the comparability of certification schemes based on this methodology.

As a first step, we describe the sources of the likely substantial underestimation and low comparability of the fugitive CH_4 emissions. In a second step, we discuss the possible impact.

Sources of potential underestimation of fugitive CH4 emissions:

We have identified three sources of a potential underestimation of the fugitive CH_4 emissions.

1) The draft IPHE Methodology (Section B.5., page 49 ff.) suggests that the “embodied emission factor for natural gas [$kgCO_{2eq}$/kg]” may be “derived from primary or secondary data, provided by supplier or sourced from relevant source i.e. National Greenhouse Account factors”. The draft IPHE methodology does not provide any other indication on how to quantify the embodied emission factor for natural gas nor it requires any kind of third-party verification.

The embodied emission factor refers to the GHG emissions caused by the extraction, storage, transportation and, when applicable, liquefaction/regassification of the natural gas used as input for H_2 production. A large part of these emissions consists of unintentional or intentional fugitive CH_4 emissions that may occur at the extraction site and along the transport chain to the H_2 production site. Another smaller part consists of CO_2 and CH_4 emissions associated with the energy used to extract, store, transport and, where applicable, liquify and regasify the natural gas on the way to the H_2 production site.

The first option allowed by the draft IPHE methodology (sourcing data from natural gas suppliers) is likely to result in underestimations, as some natural gas suppliers may have a vested interest in underestimating the emissions embodied in the product they sell (and which they or their suppliers also extract, store and transport). It is difficult to conceive how embodied GHG emission data provided by natural gas suppliers from different countries and continents, without any provision for third-party verification, could be considered as a credible source of information, and as comparable with each other.

Also the second option allowed by the draft IPHE methodology (sourcing data from National Greenhouse Account (NGA) factors) might be subject to underestimations and to limited comparability. For instance, recent studies show that the real level of fugitive CH_4 emissions is significantly (factor 1.7, or even more) higher than previously reported by the United States Environmental Protection Agency.[5]

[5] Alvarez, Ramón A. et al. (2018): Assessment of methane emissions from the U.S. oil and gas supply chain, in. Science, Vol 361, Issue 6398. Elkind, Jonathan et al. (2020): Nowhere to Hide: Implications for Policy, Industry, and Finance of Satellite-Based Methane Detection. Columbia University SIPA, Center on Global Energy Policy. Howarth, Robert W. and Jacobson, Mark Z. (2021): How green is blue hydrogen?, in: Energy Science & Engineering.

Conclusion on point 1): At least one of the two options allowed by the draft IPHE methodology is likely to cause an underestimation of and an insufficient comparability between the data provided by various natural gas suppliers in many countries or by the NGA factors of different countries.

This weakness could be addressed by

- Including in the methodology a default level of assumed embodied emissions that should be based on independent, third party, public-funded scientific analysis. This third-party institution could be created around the independent International Methane Emissions Observatory, which the European Commission intends to create[6] in partnership with the United Nations Environmental Programme (UNEP), the Climate and Clean Air Coalition and the International Energy Agency (European Methane Strategy 2020).
- The default level could distinguish between different natural gas supply pathways that may impact the level of embodied emissions (e.g. conventional / fracking, distance of the H_2 production site from the main source of the gas used there, with or without LNG …). The default level should be cautiously set at a relatively high level corresponding to rather bad industry practice and it should be subject to regular revision, based on new scientific data.
- Individual H_2 producers could be given the possibility to demonstrate that the natural gas they use features a lower level of embodied emissions than the default level. The reporting used by the natural gas suppliers of the H_2 producers should be subject to third party certification and based on a clearly defined reporting standard, such as the OGMP 2.0 Reporting Framework established by the United Nations Environment Programme, in the frame of the Climate and Clean Air Coalition, of which the European Commission is a member.

2) The second source of underestimation of the impact of CH_4 emissions is that the draft IPHE methodology fails to mention and might even be interpreted as excluding the satellite-based or aerial (e.g. via drones) measurement and constant monitoring of CH_4 emissions as a key source of information.

The measurement equipment is mentioned in Section 6.2.2. (Selected cut-off criteria, pages 27-29): “if regular and/or on-line measurements are unavailable, use proxy data derived from the open literature and applicable to the H_2 production location”. The wording “regular and/or on-line measurements” does not explicitly mention satellite-based or aerial monitoring methods. This wording could even be interpreted as excluding them, since satellite and drone-based monitoring of CH_4 emissions are novel, and not regular technologies; and they are not physically on-line (although the concept of on-line measurement is prone to different interpretations).

Satellite monitoring of CH_4 emission has proven to be able to reliably detect individual leaks as well as diffuse methane emissions, for instance in extraction regions.[7] “The new wave of satellite monitoring capability has major implications for industry and governments. Our world is rapidly becoming a place in which methane emissions will have nowhere to hide”[8], as satellite monitoring

[6] European Commission, EU strategy to reduce methane emissions, COM(2020) 663 final
[7] European Space Agency (2021): Monitoring methane emissions from gas pipelines. European Space Agency (2020): Mapping high-resolution methane emissions from space.
[8] Elkind (2020), see above.

will be widely available within a few years, last but not least thanks to the leadership of the European Union and to the efforts of the European Space Agency.

Including a satellite monitoring requirement will not only help creating a level playing field by providing a more realistic view of the GHG emission intensity of different H_2 production pathways; it also will provide an incentive for the natural gas industry to effectively reduce their CH_4 emissions. In several countries, the natural gas industry is looking at “blue hydrogen” (SMR+CCS) as the new frontier for maintaining the value of their assets within the frame of stricter climate mitigation policies. The sooner and the more information is available on the real level of fugitive CH_4 emissions, the lower the risk of undetected climate damage and, ultimately, stranded investments.

Conclusion on point 2): This weakness could be addressed by an explicit mentioning and requirement of including satellite monitoring as a source of information of fugitive CH_4 emissions, both upstream and, where applicable, at the sites of H_2 production.

3) The third source of underestimation of the impact of CH_4 emissions is that the draft IPHE methodology factors in a Global Warming Potential for a period of 100 years (GWP_{100}) for methane of 28. The 28 value is outdated and too low.

The GWP indicates the impact of various greenhouse gases relative to CO_2. A value of 28 means that the global warming impact of a molecule of methane is 28 times higher than that of a molecule of CO_2. CH_4 has a much higher energy adsorption than CO_2, but a shorter lifetime in the atmosphere.

As the global CH_4 emissions massively increased, among others in the wake of the “shale gas revolution”, science about the climate impact of CH_4 has been improving too. As a consequence, the GWP_{100} of methane has been upgraded several times: from 21 in the 2nd IPCC Assessment Report, to 25 in the 4th IPCC Assessment Report[9] and, at latest by 2014[10], to 28, which is the value indicated in the IPHE methodology (section 6.2.3., page 28), quoting an IPCC source of 2018. In August 2021, the IPCC published a further upgrade of the GWP_{100} for methane to 30[11], i.e. 7% higher than the value of 28 assumed by the draft IPHE methodology. And this might not be the last upgrade: For instance, the United States Environmental Protection Agency estimates a GWP_{100} for methane in the range of 28-36[12].

Conclusion on point 2): The IPHE methodology should upgrade the GWP_{100} of methane from 28 to 30, according to the latest findings of IPCC. Although some IPHE member countries may need time to adapt their National Greenhouse Gas Accounts to the latest findings of the IPCC; we see no reason why the newly defined methodology for determining the GHG emissions associate with H_2 production should from its very start refer to an outdated GWP of methane.

[9] Greenhouse Gas Protocol: Global Warming Potential Values.
[10] Siehe Seite 87, in: IPCC: Climate Change 2014 Synthesis Report.
[11] See table 7.15, page 7-125, in IPCC AR6 WG1 2021, Climate Change 2021: The Physical Science Basis, full report, version for final government distribution.
[12] US EPA: Understanding Global Warming Potentials.

High impact of a possible underestimation of CH_4 emissions

The importance of the analysis and recommendations above is supported by the following considerations:

- Methane is after CO_2 the second most important greenhouse gas
- A growing amount of literature shows that GHG emissions embodied in the natural gas are an important, possibly the most important part of the GHG emissions associated with H_2 produced via SMR with CCS.[13]
- The literature shows that the estimations about the share of fugitive CH_4 emissions – i.e. the share of methane that is deliberately or accidentally emitted on the way from well to the customer - has been substantially increasing over time. Parkinson et al (2019) report that many previous studies used a value of 1.22%, based on an outdated model of the US Department of Energy; the 2017 IEA World Energy Outlook assumed a value of 1.7%. Howarth and Jacobson (2021) estimate 3.5%.
- An underestimation and/or a lack of comparability of the CH_4 emission data would significantly distort the comparability of the GHG emission intensity calculated following the draft IPHE methodology, creating a bias in favor of the H_2 production pathways that are more CH_4 emission intensive, especially SMR with or without CCS. However, CH_4 emissions are relevant also for H_2 from coal gasification (CH_4 emissions from coal mining) and for H_2 from electrolysis, if the electricity is taken from the grid and the grid entails significant shares of electricity from natural gas or coal.
- Such distortions might seriously jeopardize the credibility of certification schemes based on the draft IPHE methodology.
- Well to gate implies that activities associated with the decommissioning of the facility (e.g. fugitive associated with post-mining activities) should be excluded. This could create a bias for specific pathways of H2 production, as the specific (pro unit of H2 produced) methane emissions linked to dismissed gas wells or coal mines might be higher or lower (probably they are higher) than the emissions related to decommissioning for instance wind or solar equipment.

2 Electricity input

Treatment of the electricity input is defined in section 6.3.3.4.1 of the IPHE methodology. It distinguishes between

- on-site electricity generation and
- electricity from the grid.

System boundaries are defined for on-site electricity generation. "*When electricity is internally generated (e.g. on-site generated electricity) and consumed for the investigated hydrogen production process and no contractual instruments have been sold to a third party, then the*

[13] See Howarth & Jacobson 2021, Barrett and Gallo Cassarino [preprint], both quoted above.

emissions would be any scope 1 emissions resulting from generating that electricity […]" [p.33]. However, this must be checked upon in regular technical audits.

Our analysis focusses on the treatment of GHG emissions when using electricity from the grid. On page 33 and following the draft IPHE methodology suggests two options for the calculation of GHG intensity of electricity input for hydrogen production: using the *location-based approach* (being either national average emissions intensity or another grid average) or the *market-based approach* (i.e. GHG emissions from the individually contracted sources of electricity).[14]

The draft IPHE methodology does not provide incentives for investments into additional RES-E generation which is needed for green hydrogen production. If such additional RES-E generation is not stimulated, RES-E generation for green hydrogen will just be virtually removed from the existing demand market. At the same time, in many cases fossil power plant have to increase production to meet the increase of overall power demand by the increase of hydrogen production. This leaves other electricity consumers with a more polluting power mix, and an overall increase of CO_2-emissions within the system because of the hydrogen production. To avoid this negative effect, the deployment of additional RES-E needs to be further addressed.

On page 33 of the IPHE methodology it is stated that "*[…] Market-based data will be used where possible to calculate emissions-intensity of hydrogen production […]*". From this, it can be expected that RES-E certificates (like guarantees of origin - GOs - in Europe) will be of heavy interest for proving that the electricity input is based on RES-E. Buying RES-E certificates will presumably be possible at far lower cost than using the also mentioned power purchase agreements (PPAs). From our point of view this will have the following implications / lead to following problems:

- In many countries with high potentials for low costs hydrogen production there is neither a national GO system in place nor a suitable audit system. In principle, the quality criteria for contractual instruments (reference to GHG Protocol Scope 2 Guidance) are considered adequate. However, it should be closely assessed how strict these criteria are interpreted, implemented and verified.
- There is no definition within the methodology if the sourcing RES-E production plants for PPAs or Certificates of Origin must be placed within the same grid or region. It only states that there must be *"[…] a dedicated transmission line between the organization and the generation plant from which the GHG emission factor is derived […]" [p. 33].* Besides this, the referenced scope 2 quality criteria for contractual instruments requires that such instruments *"Be sourced from the same market in which the reporting entity's electricity-consuming operations are located and to which the instrument is applied."* (GHG Protocol Scope 2 Guidance, Table 7.1), while the term "market" can be widely interpreted. Therefore, GOs could be used form other regions or countries at low cost not contributing at all to any uptake of RES-E within the given region or country of hydrogen production.
  Furthermore, with the potentially broad geographic scope for contracting RES-E production, also the potential supply volume from existing RES-E plants increases. This means that it can be hardly argued that an increase of green hydrogen production would automatically lead to an increase of RES-E production.

[14] See section 6.3.3.4.1. b) and definitions in section 5 of the IPHE methodology.

- If hydrogen exporting countries implement a GO-System for electricity just in time to support the production of “green” hydrogen it is likely that there will not be any demand for GOs within the country. Therefore, hydrogen production will only “claim” the green property of the electricity, while other market participants will not even take note of the increased GHG emission factor associated with their supply, and without any contribution to an uptake of RES-E.
- As a conclusion, one can state that neither the market-based method in the proposed form nor the location-based method provides incentives that RES-E generation is increased according to additional electricity demand from electrolysis, or that any such increase would be made transparent.

In many countries there is no reporting mechanism in place to determine the GHG emissions of electricity in the grid according to the “location-based method”. Also, using GHG emission factors from small regions (State or Provinces) can strongly deviate from the real system-wide effects on GHG-emissions.

The draft IPHE methodology suggests for the *“[…] location-based method to depict emissions with reference to the average emissions from the relevant regional grid”* [p.33].

While in the EU there are strong reporting mechanisms in place for grid operators to provide data on the GHG emissions, this is not the case in all countries that might want to export hydrogen. Also, it is not secured that data for GHG-emissions are comparable between countries. This issue of data availability and quality of the data should be more in focus within the methodology.

Furthermore, the methodology defines a preference for the use of state or province level grid factors over the use of country level factors: “*State or province level grid factors are preferred but country level grid factors may also be applied if State or province factors are not available*.”[p.34] Using GHG emission factors from small regions can strongly deviate from the real system-wide effects. This is due to the mechanism that electricity demand and generation are being balanced within a balancing zone, which must not be identical with states or provinces.

The application of the contractual market-based emission factor does not incentivise flexible H_2 production, focusing on times of high RES-E generation and low emission factor.

With a view to the perspective of increasing shares of intermittent renewable shares in national power systems it would be helpful that hydrogen production plants are incentivized at least in the medium term to learn to be operated in a flexible way in order match production times with times of high energy shares in the system mix. It is worth noting that this is enhanced by application of the hourly grid mix emission factor in the location-based method.
Besides this, in rare cases of power system with a very high share of RES-E already today, such flexible operation could use excess RES-E production in times when this would be curtailed.

Requirements for avoiding double-counting of RES-E are in place, but may in practice be more a plain technical measure than a contribution for supporting the increased deployment of RES-E

The methodology states that a residual mix factor should be applied to mitigate double counting. However, requirements for the application of a residual mix are very general. The actual application of residual mix by other parties would have to be enforced in order to safeguard the unique claim of contractual instruments and to avoid double counting, but at the same time, such application is beyond the power of decision of any hydrogen actor. Furthermore, as long as no general fuel mix disclosure regulation is in place in the region of the RES-E production plant, existing RES volumes are just claimed for hydrogen production, without any visibility for most other electricity consumers that their fuel mix becomes less green (and the related emissions are thus higher). Thus, no incentive is given for any increase of RES-E volumes if RES production is sufficient to cover the explicit demand of hydrolysers and individual other (commercial) consumers.

Dual reporting helps seeing the big picture (both market-based and location-based approach), but although this is required, there is obviously a priority for the market-based approach.

On page 33, it is stated that the proposed methodology is consistent with the GHG protocol, including dual reporting requirements consisting of a location-based and market-based method. If such a dual reporting is applied consequently it helps getting a more meaningful picture of the individual efforts (using contractual instruments) and the system-wide effects of the hydrogen production (by the use of the average mix). However, both the methodology and the referenced GHG protocol suggest a priority for the market-based method if possible, thus suggesting that in the end GHG related communication should be finally based on this aspect. This weakens the possibility for taking system wide effects into account, particularly when considering that the market-based approach in the described form does not incentivise the deployment of new RES-E. Therefore, additional requirements would be needed.

The draft IPHE methodology allows for the flexible definition of production batches (5.2.1. and 5.2.2 and A5) and sub-batches. Especially sub-batches are not clearly defined, and the term is not being used within the description of evaluation methods.

The draft IPHE methodology does not clearly state if average grid mix emission factors must be used for a whole batch. Another option could be that quality differentiation within the (sub-)batch according to the shares of different energy sources within the grid mix can be made. This way production of green hydrogen could be reported without purchasing GOs and without any contribution to RES-E deployment which would lead to increased production from fossil electricity generation plants and hence increased CO_2-emissions.

Some points of the methodology are not sufficiently explained or elaborated, which leaves room not only for inconsistencies but also for misinterpretations.

Obviously, not all relevant aspects can be elaborated to full level of detail in such a first version of a methodology, also considering the broad geographical scope of the methodology. However, the following aspect could probably be easily clarified and should therefore be further addressed:

- In general, GHG impact of electricity generation from wind, PV, hydro and geothermal is assumed to be zero [footnote on p.29]. However, the draft IPHE methodology refers to countries where such electricity represents avoided emissions so that GHG impacts are not considered zero and the residual mix concept is not applicable. The meaning and relevance of the case of “avoided emissions” does not become sufficiently clear (i.e. is this referring to national inventories, or to corporate carbon footprints, …). Furthermore, it is not clear how GHG impacts should be considered instead of zero (e.g. no application of market-based approach at all, or application of a deviating positive or negative emission factor for RES, …). This should be clarified.

3 CO_2-Allocation

The IPHE paper puts a lot of focus on the allocation of CO_2 emissions when hydrogen is a by-product in industrial processes (using fossil fuels) or produced from fossil feedstocks with steam reforming or coal gasification. The methodology is described in a very theoretical way in Chapter 6 but is basically methodologically robust. However, one method should be clearly suggested to generate robust results for similar processes. Therefore, the appendix with examples is very helpful. However, the methods are put side by side without any hint which method should be used (e.g. for chlorine electrolysis). This leads to a large bandwidth of results throughout the various methods. Here, a stronger conclusion would have to be drawn that one cannot simply choose one method.

4 CCS

Our only remark is that table 4 of the draft IPHE methodology (Section B.3., pages 47 ff.) correctly counts fugitive CO_2 from transportation and from the permanent storage location as emission sources, but it does not mention fugitive CO_2 emissions that may occur in the process of injecting the CO_2 into the permanent storage location.

For the sake of completeness, we suggest that the emissions during the injection phase be explicitly mentioned.

5 Comparing IPHE Methodology to other regulations and methodologies

This chapter compares how the draft IPHE methodology fit with selected certification schemes or hydrogen policy documents at EU level or in some EU Member States.

5.1 European Hydrogen Strategy

The draft IPHE methodology is not or not fully compatible with the principles of the European Hydrogen Strategy in the following major issues:

- Regarding green hydrogen the European hydrogen strategy formulates specific requirements for the electricity input for electrolysis, which are not considered by the draft IPHE methodology:
  - a form of additionality of RES-E generation,
  - a correlation in time between RES-E generation and hydrogen production
- The European Hydrogen Strategy also aims at the raw materials needed for hydrogen production. However, additional sustainable issues are not considered in the draft IPHE methodology.
- The European Hydrogen Strategy states in various parts the need for a full life-cycle analysis. The draft IPHE methodology in contrast does not include the GHG emissions of capital goods (partial scope 3 approach).

The European Hydrogen Strategy[15] sets goals and outlines a pathway for the uptake of hydrogen. Even though it does not suggest specific methodology for determining GHG emissions from the production of hydrogen, it formulates some guidelines that can be compared to the draft IPHE methodology.

[15] European Commission (EC) (2020): A hydrogen strategy for a climate-neutral Europe. COM(2020) 301, , 8 July 2020.

The European hydrogen strategy formulates an element of **correlation in time with RES-E generation**: *"[…] demand for electricity for hydrogen should be enabled in particular at times of abundant supply of renewable electricity in the grid". [p. 13]*

➔ The aim of the strategy is therefore to incentivise hydrogen production via electrolysis in times with high shares of RES-E within the system. However, as analysed in section 2, the draft IPHE methodology does not incentivise this kind of operation.

The European strategy assumes that a form of **additionality of RES-E** is needed for supplying electricity for the electrolysis: "*Up to 33 TWh of renewable hydrogen could be produced by either directly connecting renewable electricity to the electrolysers, or by ensuring that certain conditions are met, including the additionally of the renewable electricity used."* [p.5]

➔ This is not addressed in the draft IPHE methodology, which does not include the criteria of additionality and presumably only leads to minimal additional RES-E deployment in case GOs are being used.

Regarding the **GHG-Emissions of hydrogen production** based on RES-E the European hydrogen strategy states: *"The full life-cycle greenhouse gas emissions of the production of renewable hydrogen are close to zero."* [p.3]. Hence, the European Hydrogen Strategy contains partly contradictory statements: on one hand, it intends to take into account "full life-cycle GHG emissions" from hydrogen production (see citation above) on the other hand it states that the the full life-cycle greenhouse gas emissions of the production of renewable hydrogen are close to zero (see citation above). This is not true as long as the production of e.g. wind turbines or solar equipment is associated with GHG emissions.

➔ The draft IPHE methodology states that *"Scope 1 emissions from electricity use are considered to be zero if on-site renewable electricity is used."* [p.35]. and *"As a result, the GHG impact of electricity generation from wind, solar photovoltaic, hydropower and geothermal will be assumed to be zero […]"* [p.30] .This does not include emissions from the production of RES-E plants such as wind turbines or PV panels and is not in line with the European hydrogen strategy which requires a full life-cycle approach.

The European hydrogen strategy also addresses **requirements on the raw materials needed** in the equipment to produce hydrogen: *"In addition, it will require a large amount of raw materials […]. Securing these raw materials should, therefore, be also looked at in the Critical Raw Materials Action Plan, the implementation of the new Circular Economy Action Plan, and EU's trade policy approach to ensure undistorted, fair trade and investments in those raw materials. A life-cycle approach is also needed to minimise the negative climate and environmental impacts of the hydrogen sector."* [p.10]

➔ Further sustainability issues like raw materials are not part of the draft IPHE methodology.

5.2 European Methane Strategy

- The draft IPHE methodology is not aligned with the European Methane Strategy, for three main reasons:
  - The European Methane Strategy recognises the need for an accelerated effort to tackle methane (CH_4) emissions, whereas the draft IPHE methodology is likely to significantly underestimate the CH_4 emissions linked to hydrogen production, thus creating a bias in favour of the H2 production pathways that are more CH4 emission intensive, especially "blue hydrogen", i.e. SMR+CCS (see above)
  - The European Methane Strategy aims at creating an independent international body to monitor CH_4 emissions and verify company reporting in this filed, whereas the draft IPHE methodology relies only on company reporting (see above)
  - The European Methane Strategy gives great importance to satellite and drone based CH_4 emission monitoring, whereas the draft IPHE methodology fails to mention them and could even be interpreted as excluding them.

The European Methane Strategy [COM (2020) 663] of October 2020 acknowledges the fact that the new European climate goals "*require an accelerated effort to tackle methane emissions*" [p. 1]. The legislative proposals announced in the EU Methane Strategy have not been tabled yet, but the spirit of the strategy is clear.

It states that "*the most cost-effective methane emission savings can be achieved in the energy sector. Upstream oil and gas operations generally have a variety of mitigation options that have no net costs, or near zero costs*" [p. 1]. This is among others due to the fact that, unlike other methane emitting sectors, the energy sector can achieve the most demanding (Tier 3) approach for reporting methane emissions. "*One of the key objectives of this strategy is to make Tier 3 methane reporting by energy, chemical and agricultural companies more widespread* (…) *In the energy sector, Tier 3 reporting is achievable for industry and will therefore be the EU target standard. Widespread adoption of the measurement and reporting framework developed under the Climate and Clean Air Coalition (CCAC) Oil and Gas Methane Partnership (OGMP) will accelerate this transition (see more details under actions in the energy section).The new OGMP standard (OGMP 2.0) commits participating companies to increase the accuracy and granularity of their methane emissions reporting for operated and non-operated assets in 3 and 5 years respectively.*"

Furthermore, the European Methane Strategy announces the establishment of an independent international methane emissions observatory, in partnership with the United Nations Environmental Programme, the International Energy Agency and the Climate and Clean Air Coalition, The observatory will be "*tasked with collecting, reconciling, verifying and publishing anthropogenic methane emissions data at a global level.*"

Finally, the European Methane Strategy points to the key role that satellite detection and aerial monitoring (the latter e.g. by drones) can play for the collection of data on (global) methane emissions, and for the verification of company reporting. The European methane strategy elaborates on the extensive efforts of the EU to strengthen the satellite-based capability for detecting and monitoring fugitive methane emissions.

All in all, the draft IPHE methodology is not aligned with the European Methane Strategy, for the same reasons mentioned in Chapter 1 above:

➔ Concerning the emissions embodied in the natural gas used for H_2 production (mainly fugitive CH_4 emissions), the draft IPHE methodology relies on data reported from gas suppliers, whereas the European Methane Strategy develops a strategy for a third-part measurement and verification.

➔ The draft IPHE methodology does not mention and even could be interpreted as excluding the satellite or aerial monitoring of fugitive CH_4 emissions, whereas these technologies are of essential importance for the European Methane strategy.

5.3 Recital 90 - Renewable Energy Directive (RED-II)

Three out of four main elements within Recital 90 are not addressed in the draft IPHE methodology:

- There is no element of additionality of RES-E generation.
- There is no element of temporal correlation between RES-E generation and hydrogen production.
- The geographical correlation between hydrogen production and RES-E generation is less strict within the draft IPHE methodology.

The RED II states the following criteria for the use of electricity from the grid to produce Renewable Fuels of non-biological origin (RFNBOs) in Recital 90: Renewability of power purchase, Additionality of RES-E sources, temporal correlation, and geographical correlation. The delegated act is still pending.

Renewability: The draft IPHE Methodology also formulates the option to purchase GOs. Using GOs to prove renewable electricity input for hydrogen production will be the cheaper option compared to contracting long term PPAs.

Additionality: This element of RES-E additionality is <u>not</u> part of the IPHE Methodology as already explained in the “electricity input” chapter of this paper.

Temporal correlation: An element of temporal correlation between contracted RES-E generation and hydrogen production is not part of the IPHE methodology. In case of sourcing electricity from the grid, the draft IPHE methodology suggests using the average hourly grid emission factor.

Geographical correlation: The definition of “physical grid connection” in the draft IPHE methodology can be interpreted quite broadly. Please also refer to chapter “electricity input” for further detailed information.

5.4 CertifHy

Overall, the CertifHy methodology is more detailed and stricter in some cases:

- Differentiation of batch production into hydrogen batches of different qualities and carbon intensities in one plant is more limited.
- CertifHy applies clear qualification criteria for the distinguished H_2 qualities “Green Hydrogen” and “Low-carbon Hydrogen”
- Standardisation of H_2 output pressure level in the calculation method leads to higher comparability of data.

General Information about CertifHy

- The CertifHy projects (phase 1 and phase 2) have led to the definition of criteria for “CertifHy green hydrogen” and for “CertifHy low-carbon hydrogen”. These are applied in test applications in order to issue tradable CertifHy guarantees of origin for hydrogen. In the third phase of the project CertifHy) is currently working on the development and implementation of H_2 certification systems in line with the RED II in Europe in the period up to 2023.
- With the collaboration of the Association of Issuing Bodies (AIB), a market-compatible[16] system H_2 proof of origin system is to be developed and implemented and applied at least in individual pilot countries. The focus is on green hydrogen according to the requirements of RED II, but the development of a tracking system for non-renewable hydrogen (blue hydrogen) should also be included in the system if possible.
- In addition, a certification system is to be developed that ensures compliance with the requirements of RED II for Renewable Fuels of non-biological origin and, in this sense, is to be recognized by the Commission as a voluntary verification system.
- By bundling both objectives in one project, it is hoped that useful synergies will be exploited in addressing the respective objectives and that a high degree of coordination will prevent double counting.
- As a basis for a future hydrogen certification system, CertifHy offers a very broad foundation with high relevance. However, it would have to be ensured that CertifHy also takes into account all the criteria considered necessary (either by checking the corresponding qualification criteria and at least by recording the parameters required for this), and that blue hydrogen is also addressed to a sufficient extent in addition to green hydrogen.

Comparing CertifHy to the IPHE Methodology

CertifHy also references to the ISO standards regarding the **GHG footprint calculation**. This is similar to the proposed IPHE methodology (see Chapter 6.1). In detail CertifHy references to ISO 14040/14044 and ISO 14067 and the Annex V and Annex VI of RED II by applying them analogously to H_2. The CertifHy method also follows the “well to gate” principle when calculating GHG emissions, like the proposed IPHE methodology. GHG emissions are expressed as CO_{2eq}/MJH_2 rather than CO_{2eq}/kWh (but can be easily compared by using a correlation factor).

“Green” and “low carbon” hydrogen: Issuing of “green” or of “low carbon” H_2 GO can relate to individual shares or **production batches** of a hydrogen plant, however, benchmarks for the “overall performance” apply. CertifHy defines a benchmark by using a CO_2 factor of the hydrogen plant. Issuing of “green” or “low-carbon” GO for hydrogen is only possible if the overall CO_2 emission factor of non-Certifhy H_2 production in the past 12 months does not exceed a given benchmark (being of $91gCO_{2eq}/MJ_{H2}$). (Hinicio 2019, pg. 14) Average GHG intensity of H_2 covered by a CertifHy GO within a given production period must not exceed 36.4 gCO_{2eq}/MJH_2. GOs are then issued on a pro rata basis according to the shares of energy input for the given production period (Hinicio 2019, pg. 19). The share is to be calculated based on its energy content using the lower calorific value (CertifHy 2019).

[16] In practice, this means that the guarantees of origin should be in line with the European Energy Certificate System (EECS), which is established and maintained by the AIB.

RES-E consumption for the issuing of **green H_2 GO** is to be documented **solely by cancelled RES-E GOs** (CertifHy 2019 pg. 8, LBST 2019, pg. 18), this means that the location-based approach is not applicable with a view to CertifHy Green H_2 GO. Issuing of CertifHy Low-Carbon H_2 GOs based on the location-based approach is possible if the respective average emission factor is below the given threshold (Hinicio 2019, pg. 20).

➔ The IPHE Methodology does not strictly distinguish between green, grey and low carbon H_2. RES shares in the applied electricity mix are reflected in the applied emission factor, irrespective of the specific methodological approach.

The GHG impact of electricity used for H_2 production shall be zero for electricity from wind, solar photovoltaic, and hydropower (CertifHy 2019, LBST 2019)

➔ This is in line with the IPHE Methodology.

Calculation of GHG balance according to CertifHy needs to assume at least a pressure at the boundary limit of 3 MPa. This means that in cases where the pressure at the boundary limit of the hydrogen plant is below that threshold, the energy which would be needed to reach this threshold value needs to be virtually added in the consideration, and the respective RES-E GOs need to be cancelled.)

➔ Such specifications are not considered in the IPHE Methodology, possibly leading to a reduced comparability of data.

Literature

- CertifHy (2019): CertifHy-SD Hydrogen Criteria, last update 2019-03-13 https://www.certifhy.eu/images/media/files/CertifHy_2_deliverables/CertifHy_H2-criteria-definition_V1-1_2019-03-13_clean_endorsed.pdf
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- LBST (2019): Matthias Altmann, LBST: Endorsement of CertifHy Scheme Document & Subsidiary Documents; Presentation at the CertifHy 2 Stakeholder Platform; Brussels, 25 March 2019 ()
- Matthes, Felix Chr.; Heinemann, Christoph; Kasten, Peter; Bürger, Veit; Braungardt, Sibylle; Hermann, Hauke et al. (2021): Die Wasserstoffstrategie 2.0 für Deutschland. Öko-Institut. Berlin. Online verfügbar unter https://www.stiftung-klima.de/app/uploads/2021/06/Oeko-Institut-2021-Die-Wasserstoffstrategie-2.0-fuer-Deutschland-1.1.pdf, zuletzt geprüft am 14.07.2021.

5.5 TÜV SÜD CMS70

Overall, the TÜV SÜD CMS70 regulation is stricter in some sense compared to the draft IPHE methodology.

- It applies clear qualification criteria for the H_2 (particularly also including criteria on additionality of RES-E) for which GOs should be issued.
- TÜV Süd CMS70 includes emissions from the transport of H_2 to the consumer.
- Standardisation of H_2 output pressure level in the calculation method leads to higher comparability of data.

General Information about TÜV SÜD CMS70

The TÜV SÜD CMS70 standard focuses exclusively on green hydrogen. It aims to be compatible with CertifHy and applies additional features on top.

Comparing TÜV SÜD CMS70 to the IPHE Methodology

TÜV SÜD requests that RES electricity supply must come from unsupported RES-E. Supported RES-E is only eligible if the support is based on competitive mechanism (auction in the sense of RED II). Also, RES electricity supply must have minimum shares from new plants or fluctuating energy sources:

- Option 1: > 30% of new plants (max. 36 months at the beginning of the contractual supply, max 10 yrs in total)
- Option 2: fund model (0.2 EURct/kWh for energy transition projects)
- Option 3: technology mix (excluding e.g. large hydro or large biomass plants)

➔ This is much stricter compared to the IPHE Methodology. However, TÜV SÜD suggests a certification criteria and not solely a calculation method.

TÜV SÜD also suggests consumption related criteria for the H_2 certificate.

➔ This will be part of later publications by IPHE.

The calculation of greenhouse gas emissions of green hydrogen must include the production of the feedstock, and the transport of the H_2 to the consumer (respectively H_2 station).

➔ For the time being, IPHE only covers emissions within a well-to-gate approach.

RES-E must be documented either by verified on-site production or by cancelled RES-E GOs.

➔ This is stricter compared to IPHE Methodology as grid mix is not applicable.

Calculation of GHG balance needs to assume at least a pressure of 30 bar.

➔ Such specifications are not considered in the IPHE Methodology, possibly leading to a reduced comparability of data.

Literature

- TÜV SÜD Standard CMS 70: Erzeugung von Grünem Wasserstoff (GreenHydrogen), last updated: 8. Januar 2020 https://www.tuvsud.com/de-de/-/media/de/industry-service/pdf/broschueren-und-flyer/is/energie/standard-cms-70-greenhydrogen-ts-is-ut.pdf?la=de-de&hash=73E98931F8657D0313E27ED725C6B45D

5.6 Netherlands Enterprise Agency Program: Stimulation of sustainable energy production and climate transition (SDE++)

SDE++ is a support scheme managed by the Netherlands Enterprise Agency, which supports projects in various fields related to renewable energy production, energy efficiency, CCS. Hydrogen production is supported only via electrolysis.

"*For each technique, the 'operating shortfall' is subsidised. This is the difference between the cost price of the technique that reduces the CO2 (the 'base amount') and the market value of the product giving rise to the technique (the 'correction amount').*"[17]

No specific methodology can be found on how the CO_2-intensity of hydrogen production based via electrolysis should be calculated.

Instead, the SDE++ Program defines maximal Full-load hours for electrolysers, which rise from 2940 hours in 2021 to 5000 hours in 2026. It can only be assumed that the operator is allowed operate up to this number of full-load hours per year in which CO_2-emissions of 0 g CO_2 will be associated to the hydrogen produced. [18] Like in the draft IPHE methodology, additional RES-E generation and temporal correlation to RES-E generation is not considered.

5.7 French hydrogen decree 2021-167 and Ademe's lifeycle analysis

In France, the decree n° 2021-167 of 17 February 2021[19] has established the definition of three kinds of H_2 production pathways: renewable hydrogen, low carbon hydrogen and (ordinarily high) carbon hydrogen. For H_2 to be qualified as renewable or low carbon, the production process may result in emissions lower than a threshold, which still has to be defined by an additional legal source that has not been adopted yet. The decree 2021-167 does not contain any further specific indication concerning the methodology to quantify the emissions.

In 2020, the French Agency for Ecological Transition (ADEME) produced a study on the life-cycle emissions for hydrogen-based mobility applications, which includes an assessment of difference H_2 production pathways. Based on the result of the study, ADEME has published the following list of emission factors[20], which ranges from 19.8 $kgCO_2/kgH_2$ for electrolysis based on the European electricity mix, to 11.1 $kgCO_2/kgH_2$ for steam methane reforming, to 2.77 $kgCO_2/kgH_2$ for electrolysis based on the French electricity mix, 2.58 $kgCO_2/kgH_2$ for electrolysis based on PV, 0.7 $kgCO_2/kgH_2$ for electrolysis based on wind and 0.45 $kgCO_2/kgH_2$ for electrolysis based on hydropower. Because

17 https://english.rvo.nl/subsidies-programmes/sde/features-sde
18 https://www.rvo.nl/subsidie-en-financieringswijzer/sde/aanvragen/co%E2%82%82-arme-productie
19 https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000043148001
20 See: https://www.bilans-ges.ademe.fr/documentation/UPLOAD_DOC_FR/index.htm?hydrogene.htm (section Hydrogène \ Prodcution d'hydrogéne)

the entire study seems to be accessible only to entities registered in France,[21] it has not been possible to analyze the methodology used by ADEME to create these emission factors.

Therefore, in both cases a direct comparison to the draft IPHE methodology is not possible within this paper.

[21] An abstract of the study in English is available here. When trying to download the study "Analyse du Cycle de Vie relative à la mobilité hydrogène" from ADEME's bookshop, a mandatory field is the SIRET, a code that allows the identification of French legal entities.