Biomethane Splitting: The Hindered Carbon Removal Potential of Biohydrogen

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Abstract Biomethane splitting for hydrogen and solid carbon production is an emerging carbon removal technology. It sequesters biogenic CO_2 from biomass into solid carbon, enabling negative GHG emissions. Reported GHG emissions vary depending on the accounting framework used. This is the first study to systematically assess MS emissions across the EU Renewable Energy Directive (Red III), the UK Low Carbon Hydrogen Standard, and ISO LCA, addressing the implications of the inclusion and exclusion of biogenic CO_2 and carbon credits. GHG emissions are 2.11, −7.41, and 5.32 $kgCO_2/kgH_2$, respectively. Red III underestimates the removal potential by excluding both biogenic CO_2 and carbon credits. LCA including biogenic CO_2 results vary based on biomethane origin, creating an unfavorable scenario for biowaste biomethane. The UK standard offers the most balanced approach, recognizing credits for the solid carbon sequestration.

1 Introduction

Low emissions hydrogen is recognized by the International Energy Agency (IEA) as a strategic technology projected to contribute approximately 4% to cumulative global greenhouse gas (GHG) emissions reductions by 2050 (IEA 2024a). Its application varies from heavy goods traffic, energy balance, to hard-to-abate industries such as cement, steel, and fertilizer (IEA 2024b).

Focusing on hydrogen production today, it is based on unabated fossil fuel processes, emitting 920 Mt CO_2 annually (IEA 2024b). Low emission hydrogen accounts for only 1% of the global hydrogen produced. Specifically, in Europe, the reforming process represents 68.8% of the total production, while reforming

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with carbon capture and storage (CCS) and water electrolysis account for 0.5% and 0.4%, respectively (Hydrogen Europe 2024a). Both reforming with CCS and water electrolysis technologies present specific global and regional constraints.

Reforming with CCS is deeply related to the natural gas resources, water availability, presence of CO_2 storage sites, CO_2 transport infrastructure and policy development (Griffiths et al. 2021; IEA 2024b); while high electricity consumption, water availability, land use supply, and depletion of critical materials pose challenges for electrolysis development.

In a hydrogen economy, Methane Splitting (MS) is a possible bridging technology for climate-friendly and cost-effective hydrogen production. The reaction does not produce direct CO_2 emissions, avoiding the need for a transport and storage CO_2 system. Meanwhile, the electricity and water demands are lower than those of water electrolysis and reforming processes. MS technologies reach, today, a high-technology readiness level, ranging from 5 to 8 (Hydrogen Europe 2024; IEA 2024b). The EU and the US play a central role in the development of MS technology, with the majority of leading companies in this field headquartered in these regions (Hydrogen Europe 2024b). The EU Commission incentivizes the MS technologies development through a first and second round of research funding (Clean Hydrogen Partnership 2025). The last call for proposals specifically targets biomass and biofuel as feedstock, excluding the use of fossil fuel. When biomethane is consumed as feedstock, the MS shows carbon removal potential. The Life Cycle Assessment (LCA) study of Diab et al. 2022 calculates GHG emissions of -5.22 $kgCO_2/kgH_2$, accounting for biogenic CO_2 in the calculation. However, different results are obtained when changing the applied biofuel. The same process, consuming soybean biofuel, emits 0.52 $kgCO_2/kgH_2$, including the biogenic CO_2 (Lawson et al. 2024). The values increase to 1.41 when biogenic CO_2 is excluded. In both studies, any carbon credits are attributed to the solid carbon.

This research focuses on the possible approach for GHG calculation on biomethane splitting, with a focus on EU regulation. This is the first study to systematically assess the GHG emissions of biomethane-based MS using multiple regulatory and LCA calculation frameworks. It uniquely compares the Renewable Energy Directive (Red III) (The European Parliament and the Council of the European Union 2018), UK Low Carbon Hydrogen Standard (UK Department for Energy Security and Net Zero 2024), and ISO LCA methodologies (ISO 2006a, ISO 2006b), explicitly addressing the implications of including or excluding biogenic CO_2 and carbon credits. The analysis also considers different biomethane origins and performs a sensitivity analysis on carbon allocation, providing an unprecedented regulatory perspective tailored to the EU context.

2 Methodology

2.1 Technology Description and Study Assumptions

Methane Splitting (MS), also known as methane pyrolysis or methane decomposition, is a thermochemical process that splits methane into hydrogen and solid carbon (Eq. 1).

$$CH_{4(g)} \leftrightarrows 2H_{2(g)} + C_{(s)} \; \Delta H_0 = +74.9\text{kJ} \tag{1}$$

The primary process steps of MS comprise (1) the splitting of methane into gaseous hydrogen and solid carbon, (2) the removal of the solid carbon from the gas stream through a filter or cyclone system, and (3) the purification of the gas stream, mainly using pressure swing adsorption (PSA) or membranes. The plasma reactor has been selected for this work, as the reactor system with the highest TRL (Monolith 2025). The technical parameters of the process are indicated in Table 1. The electricity consumption is fixed at 15 kWh per kg of hydrogen in alignment with the target defined by the research call (Clean Hydrogen Partnership 2025). This is a conservative assumption, reflecting the average electricity consumption for the actual thermal plasma operation (Timmerberg et al. 2020). However, it can be optimized by lowering the reactor temperature, as demonstrated in non-thermal plasma systems. Biomethane consumption is defined as 4 kg per kg of hydrogen, in alignment with the stoichiometric limit and with the parameters identified in the literature (Postels et al. 2016). The electricity consumption from purification is sourced from Postels et al. 2016. Hydrogen delivered at atmospheric pressure is subsequently compressed to 3 bar, and the energy required for this compression is calculated in accordance with the UK GHG Emissions Calculation Guidelines (UK Department for Energy Security and Net Zero 2024).

Table 1 Biomethane splitting technical performance

	Value
Electricity consumption MS reaction (kWh/kg H_2)	15.00
Biomethane consumption (kg/kg H_2)	4.00
Electricity consumption (purification) (kWh/kg H_2)	1.67
Electricity consumption (compression 3 bar) (kWh/kg H_2)	0.76

2.2 GHG Emissions Calculation

The GHG emissions of the biomethane splitting process are calculated following three methodological approaches identified respectively in: (1) the EU Renewable Energy Directive (The European Parliament and the Council of the European Union 2018); (2) the UK Low Carbon Hydrogen Standard (UK Department for Energy Security and Net Zero 2024); and (3) LCA including biogenic CO_2. The methodologies are summarized in Table 2 and will be discussed in the following paragraphs.

A functional unit (FU) of 1 kg of hydrogen is adopted as the basis for comparison across all approaches. The final hydrogen pressure varies according to the requirements of the selected methodology. The system boundary of the study is defined based on the methodological requirements and is illustrated in Fig. 1.

For the MS process, no direct emissions are produced during the splitting process. In this case study, the process is located in Norway, and it is powered by renewable

Table 2 GHG emissions methodologies applied

Methodology	System boundaries	Threshold	Biogenic CO_2	Allocation solid carbon	Solid carbon sequestration credits	Renewable electricity GHG emissions
EU Red III	Well-to-wheel	3.4	Excluded	Energy allocation	Excluded	Excluded
UK Low Hydrogen Standard	Well-to-gate	2.4	Excluded	No allocation	Included	Excluded
LCA including biogenic CO_2	Well-to-gate	/	Included	Energy allocation	Excluded	Included

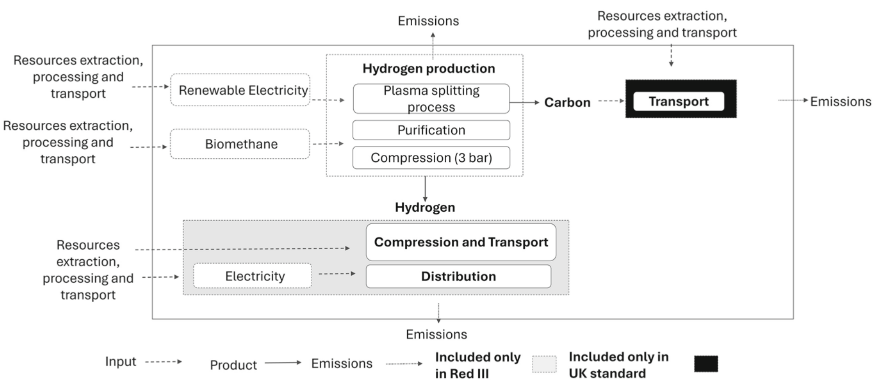

Fig. 1 System boundaries

energy. The upstream emissions of biomethane, electricity, and transport are sourced from Ecoinvent 3.11 cutoff approach by classification (Wernet et al. 2016), and Activity Browser software is used (Steubing et al. 2020). Norwegian (NO) data are selected as the primary option; when unavailable, European (ReR) data are used, and as a final alternative, Rest of the World (RoW) data are applied. Two types of biomethane are considered in the scenario analysis: (1) generic biomethane from RoW and (2) wood-derived biomethane from RoW. The biomethane data selection has been defined according to the Ecoinvent data availability. The impact assessment method applied is the IPCC 2021 GWP100 (IPCC 2021). For the EU and UK regulatory approaches, total GWP emissions, excluding biogenic CO_2, are considered. In contrast, for the LCA approach, total GWP emissions, including biogenic CO_2, are used. In this study, the carbon is assumed to be destined for incorporation into concrete or cement.

2.2.1 Renewable Energy Directive

By 2050, the European Union targets renewable hydrogen to supply approximately 10% of its total energy demand (European Commission 2025). The EU regulation for sustainable hydrogen is the (The European Parliament and the Council of the European Union 2018). It includes hydrogen from biomass origin and "renewable fuel of non-biological origin" (RFNBO). To be defined as renewable biomass has to meet the sustainability criteria, while the hydrogen GHG emissions need to stay below the GHG emissions of 3.4 $kgCO_2eq/kgH_2$. In the Red III GHG emissions methodology, the defined system boundaries are well-to-wheel. The biogenic CO_2 and renewable electricity upstream emissions are counted as 0. This approach assumes that all the biogenic CO_2 uptake from the air and sequestered in the biomass will be released, counting at the end as 0. The energy allocation approach is applied, assigning a portion of the emissions to the solid carbon by-product based on its lower heating value (LHV). The regulation does not include solid carbon as a CO_2 storage system, and any credits can be associated with it. The system boundaries are well-to-wheel, including the hydrogen distribution and storage.

In this study, the final pressure of hydrogen is fixed at 800 bar, as required in the fuel station, and the hydrogen transport and distribution stages are modeled in alignment with the study of Wulf and Kaltschmitt 2018. An average transport distance of 100 km between the plant and the fueling station is assumed, based on the range of values identified by Wulf and Kaltschmitt 2018. The GHG emissions of the electricity consumption at the fuel station are calculated using the IPCC average Norway electricity GHG emissions, excluding emissions from renewable production (Bastos et al. 2024). The upstream emissions from the electricity consumption at the hydrogen production plant are 0 because powered by renewable energy.

2.2.2 UK Low Carbon Hydrogen Standard

The UK Low Carbon Hydrogen Standard (UK Department for Energy Security and Net Zero 2024) sets a maximum threshold for the amount of GHG allowed in the production process for hydrogen to be considered "low-carbon hydrogen." It includes all the hydrogen production processes from fossil-based processes, bio-based and water electrolysis production pathways. The GHG target is fixed at 2.4 $kgCO_2eq/kgH_2$ and adopts a well-to-gate approach. The biogenic CO_2 and renewable electricity upstream emissions are counted as 0. The regulation includes solid carbon sequestration as a CO_2 capture and storage system, considering 3.664 kg of sequestered CO_2 per kg H_2. The solid carbon can be included as a sequestration system only if incorporated into concrete or cement for construction or kept in inert underground storage (e.g., disused mines and bunkers, inert landfill, and spent oil and gas wells). Emissions from solid carbon distribution have to be included in the calculation. No allocation is applied to the solid carbon. In this study, the solid carbon transport distribution is modeled with the EURO 6 transport (freight, lorry, >32 metric ton, diesel). The transport distance is fixed at 130 km, in alignment with the Product Environmental Footprint (PEF) value for suppliers located inside Europe (Zampori et al. 2019). Hydrogen transport and distribution are excluded from the system boundaries, and the final pressure is defined at 3 bar.

2.2.3 LCA Including Biogenic CO_2

The Life Cycle Assessment (LCA) approach including biogenic CO_2, is performed in alignment with the ISO 14040–14044 (ISO 2006a; ISO 2006b), carbon footprint ISO 14067 (ISO 2018) and H_2 LCA guidelines (Bargiacchi et al. 2022). System boundaries are well-to-gate. The final pressure of the hydrogen is fixed at 3 bar. In this case, the CO_2 biogenic upstream emission of biomethane is included, attributing a characterization factor of $+1$ for the CO_2 release and -1 for the CO_2 biogenic uptake during the biomass growth. While biogenic CO_2 is excluded from the H_2 LCA guideline (Bargiacchi et al. 2022), its reporting is required by ISO 14067 (ISO 2018), though is not included in the final results. This approach is selected to cover all the different methodological approaches and to compare results with the studies of Diab et al. 2022 and Lawson et al. 2024. No credits are provided to the solid carbon, excluding double counting. In alignment with the H_2 guideline (Bargiacchi et al. 2022), the electricity emissions from renewable energy production are included.

3 Results and Discussion

In this study, the GHG emissions of the biomethane splitting have been calculated following the methodological approaches of: (1) EU Renewable Energy Directive (European Parliament and of the Council 2023); (2) the UK Low Carbon Hydrogen

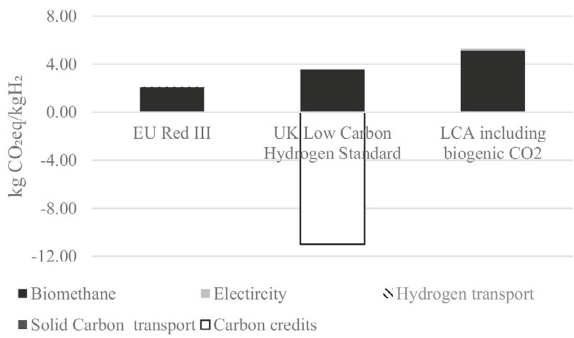

Fig. 2 Hydrogen GHG emissions ($kgCO_2eq/kgH_2$) from the biomethane splitting process following the EU Red III, UK Low Carbon Hydrogen Standard, and LCA including biogenic CO_2 emissions methodologies

Standard (UK Department for Energy Security and Net Zero 2024); and (3) LCA including biogenic CO_2. The obtained results are presented in Fig. 2, showing a range of −7.41 to 5.32 $kgCO_2/kgH_2$.

The lowest emissions of −7.41 $kgCO_2eq/kgH_2$ are observed when applying the UK low-carbon emissions approach. The biogenic CO_2 embedded in the biomass is not released but sequestered in the carbon, destined for cement and concrete products. This allows for long-term CO_2 storage, typically exceeding 100 years, and its credits can be subtracted as defined by ISO 14067 (ISO 2018). Applying this methodology, the biomethane splitting process not only is classified as low-carbon hydrogen, but also shows its carbon removal potential. However, excluding the carbon by-product from GHG emissions allocation may overestimate hydrogen's carbon removal potential, which would otherwise be partially attributed to the solid by-product.

Applying the Red III guideline, the GHG emissions are equal to 2.11 $kgCO_2eq/kgH_2$. Despite the emissions remaining below the defined threshold of 3.4 $kgCO_2eq/kgH_2$, the emissions results increased compared to the results obtained by the UK guideline. The higher results are related to the absence of carbon credits associated with CO_2 sequestration into solid carbon. Indeed, the EU guideline includes the credits only when the CO_2 is sequestered in gaseous form. The identified gap in Red III disadvantages the biomethane splitting process compared to other biohydrogen processes with a gaseous CCS system. Finally, the highest value of 5.32 $kgCO_2/kgH_2$ is observed when the GHG emissions are calculated including the biogenic CO_2. In this case, the highest emission value is attributed to biogenic CO_2 released during the biomethane production process. However, the total biogenic CO_2 uptake by biomass is not fully allocated to the biomethane, as a fraction of the feedstock originates from waste, for which no biogenic carbon uptake is assigned according to the cutoff by application standard.

Across all methodologies, upstream emissions from biomethane production contribute more than 95% of total GHG emissions, even when emissions from

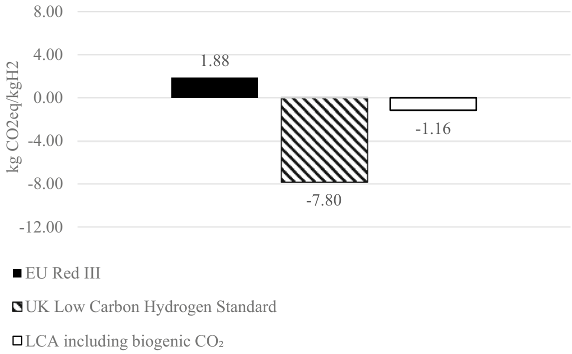

Fig. 3 Hydrogen GHG emissions ($kgCO_2eq/kgH_2$) for wood biomethane scenario

renewable electricity are included, as in the LCA, including biogenic CO_2. Considering the biomethane contribution to the hydrogen GHG emissions, a scenario analysis is performed varying the feedstock from generic biomethane to wood-derived biomethane, and results are presented in Fig. 3.

The widest variation is observed in the LCA, including biogenic CO_2, achieving a negative value of -1.16 $kgCO_2/kgH_2$. In contrast to generic biomethane, which includes the use of biowaste, the wood-based biomethane scenario allocates the entire CO_2 biogenic uptake to biomass and consequently to the biomethane. The embedded CO_2 is only partially released during the biomethanation process, whereas no biogenic CO_2 is emitted during plasma splitting, resulting in a net negative GHG outcome. Thie cut-off approach by classification in the LCA methodology disadvantages the use of biowaste compared to other biomass sources, creating a distorted scenario in which the circularity and waste valorization are undervalued from the GHG emissions point of view. Finally, the GHG in Red III and UK Low Carbon Hydrogen Standard methodologies decrease by 11% and 5%, respectively, reflecting their sensitivities to the biomethane origin.

The splitting process is characterized by two main products: hydrogen and carbon.

However, the two products present different markets in terms of volume today, and in future predictions (Dagle et al. 2017). The carbon market, although developing, is considerably smaller than the hydrogen one, risking its rapid saturation. Therefore, a sensitivity analysis is conducted on the percentage of solid carbon identified as carbon by-products and thus eligible for allocation. The remaining fraction is classified as waste and is not subject to allocation. Results are presented in Fig. 4.

In LCA, including biogenic CO_2 and EU methodology, the GHG emissions range from 5.32 to 6.97 and 2.11 to 3.57 $kgCO_2eq/kgH_2$, respectively, when the percentage of solid by-product eligible for allocation increases from 0 to 100%. A limit of 6.38% of carbon by-product is identified for the Eu Red III methodology to not exceed the regulation threshold. However, this value could change according to the upstream emissions of biomethane. In the UK Low Carbon Hydrogen Standard, the GHG emissions are unchanged to the % of eligible carbon by-product, considering no allocation applies to it. In this case, the methodology does not differentiate between carbon waste and carbon by-product.

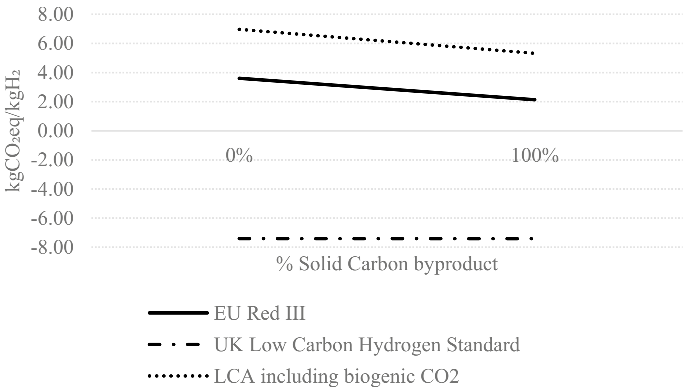

Fig. 4 Sensitivity analysis of GHG emissions ($kgCO_2eq/kgH_2$) to the % of solid carbon byproducts (eligible for allocation)

4 Conclusions

This study investigates the GHG emissions associated with the biomethane splitting process for hydrogen and carbon production. The analysis focuses on EU regulation and its comparison with the UK Low Carbon Hydrogen Standard, and ISO LCA approaches. The methodologies are selected to provide a comprehensive overview and assess the implications of including or excluding biogenic CO_2 and carbon credits. The hydrogen GHG emissions are equivalent to 2.11 (Red III), −7.41 (UK Low Carbon Standard), 5.32 (LCA including biogenic CO_2) $kgCO_2/kgH_2$. In the EU regulation, the biogenic CO_2 emissions are accounted as 0, considering that all the carbon uptake of biomass will be released, giving a final sum of 0. The solid carbon sequestered is not accounted as CCS system and no credits are attributed to it. In the UK regulations, the biogenic CO_2 is excluded, no GHG emissions are allocated to the carbon, and the solid carbon sequestration accounts for credits when its storage is assumed for more than 100 years. Specifically, when the solid carbon is destined for concrete or cement for construction or kept in inert underground storage. Finally, in the LCA including biogenic CO_2, the uptake of CO_2 and CO_2 emissions are considered in the calculation, with a characterization factor of +1 and −1. The simultaneous exclusion of both biogenic CO_2 and carbon credits in the EU regulation places MS on par with fossil-based hydrogen and at a disadvantage compared to biohydrogen pathways with gaseous CCS. Moreover, it fails to differentiate between carbon use in long-lived products (e.g., concrete) and combustion. The UK standard includes the credits from solid carbon sequestration, solving the identified gap in the Red III. However, the exclusion of solid carbon from allocation could overestimate the hydrogen carbon removal potential, which could be otherwise partly allocated to the solid by-product. The LCA methodology, including biogenic CO_2, shows the highest value among the methodologies analyzed. It is related to the biogenic CO_2 emissions of biomethane and its biomass origin. When the biomethane is sourced from biowaste, the uptake emissions will not be allocated to the biowaste, and therefore, the GHG emitted during the biomethanation is not compensated by the CO_2 uptake. However, when the biomethane source is from wood, the hydrogen shows emissions of -1.16 kgCO_2eq/kgH_2. This creates an unfavorable outcome for biowaste-derived biomethane. While including biogenic emissions with cut-off approach by classification can represent an interesting approach for LCA studies with the highest level of accuracy, its application to regulation would create a distorted scenario in regulation where the use of biowaste is disadvantaged, discouraging circular economy practices. In conclusion, this study reveals a regulatory gap in the EU framework regarding the accounting of solid carbon sequestration. This omission may lead to competitive distortions in the hydrogen market by underrepresenting the climate benefits of biomethane splitting. Additionally, it highlights the critical importance of considering the final use of carbon, whether for long-term storage or short-lived applications, in both allocation methodology and emission crediting.

References

Bargiacchi E, Puis-Samper G, Campos Carriedo F, et al (2022) D2.2 definition of FCH-LCA guidelines

Bastos J, Monforti-Ferrario F, Melica G (2024) GHG Emission factors for electricity consumption. European Commission, JRC136340

Clean hydrogen partnership, strategic research and innovation agenda—clean hydrogen partnership (2025). https://www.clean-hydrogen.europa.eu/about-us/key-documents/strategic-research-and-innovation-agenda_en (Accessed 13.06.2025)

Dagle RA, Dagle V, Bearden MD, Holladay JD, Krause TR, Ahmed S (2017) An overview of natural gas conversion technologies for co-production of hydrogen and value-added solid carbon products, pacific northwest national lab. (PNNL), Richland, WA; Argonne National Lab. (ANL), Argonne, IL

Diab J, Fulcheri L, Hessel V, Rohani V, Frenklach M (2022) Why turquoise hydrogen will be a game changer for the energy transition. Int J Hydrogen Energy 47(61):25831–25848. https://doi.org/10.1016/j.ijhydene.2022.05.299

European Commission (2025) Hydrogen. https://energy.ec.europa.eu/topics/eus-energy-system/hydrogen_en (Accessed 30.06.2025)

Griffiths S, Sovacool BK, Kim J, Bazilian M, Uratani JM (2021) Industrial decarbonization via hydrogen: a critical and systematic review of developments, socio-technical systems and policy options. Energy Res Soc Sci 80:102208. https://doi.org/10.1016/j.erss.2021.102208

Hydrogen Europe (2024) Clean hydrogen monitor 2024

IEA (2024b) Global hydrogen review 2024

IEA (2024a) Net Zero Emissions by 2050 Scenario (NZE)—global energy and climate model—analysis. https://www.iea.org/reports/global-energy-and-climate-model/net-zero-emissions-by-2050-scenario-nze (Accessed 10.02.2025)

ISO (2006a) ISO 14040:2006(en), Environmental management—Life cycle assessment—Principles and framework

ISO (2006b) ISO 14044:2006(en), Environmental management—Life cycle assessment—Requirements and guidelines

ISO (2018) ISO 14067:2018 Greenhouse gases—Carbon footprint of products—Requirements and guidelines for quantification

Intergovernmental Panel on Climate Change (IPCC) (2023) The earth's energy budget, climate feedbacks and climate sensitivity. In: Climate change 2021 – The physical science basis: working group I contribution to the sixth assessment report of the intergovernmental panel on climate change. Cambridge University Press, pp 923–1054

Lawson R, Dasappa S, Diab J, McCormick M, Wyse E, Hardman N, Fulcheri L, Dames E, Biodiesel surrogate and ethane evaluation for green carbon black and turquoise hydrogen synthesis via thermal plasma. Energy Convers Manag 302:118149. https://doi.org/10.1016/j.enconman.2024.118149

Monolith (2025) Homepage. Monolith. https://monolith-corp.com. Accessed 1 Jul 2025

Postels S, Abánades A, von der Assen N, Rathnam RK, Stückrad S, Bardow A (2016) Life cycle assessment of hydrogen production by thermal cracking of methane based on liquid-metal technology. Int J Hydrogen Energy 41(48):23204–23212. https://doi.org/10.1016/j.ijhydene.2016.09.167

Steubing B, de Koning D, Haas A, Mutel CL (2020) The activity browser—an open source LCA software building on top of the brightway framework. Softw Impacts 3:100012. https://doi.org/10.1016/j.simpa.2019.100012

The European Parliament and the Council of the European Union (2018) Directive (EU) 2018/2001 of the European Parliament and of the council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast) (Text with EEA relevance)

Timmerberg S, Kaltschmitt M, Finkbeiner M (2020) Hydrogen and hydrogen-derived fuels through methane decomposition of natural gas—GHG emissions and costs. Energy Convers Manag X(7):100043. KEIPI

UK Department for Energy Security and Net Zero, UK low carbon hydrogen standard: greenhouse gas emissions methodology and conditions of standard compliance (2024)

Wernet G, Bauer C, Steubing B, Reinhard J, Moreno-Ruiz E, Weidema B (2016) The ecoinvent database version 3 (part I): overview and methodology. Int J Life Cycle Assess 21(9):1218–1230. https://doi.org/10.1007/s11367-016-1087-8

Wulf C, Kaltschmitt M (2018) Hydrogen supply chains for mobility—environmental and economic assessment. Sustainability 10(6):1699. https://doi.org/10.3390/su10061699

Zampori L, Pant R, European Commission (eds) (2019) Suggestions for updating the organisation environmental footprint (OEF) method, Publications Office, Luxembourg