BRIEFING

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Defining low-carbon gas and renewable gas in the European Union

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SUMMARY

The European Union aims to scale up low-carbon gas and renewable gas to decarbonize the gas sector. However, the gas definitions are not clear, and lacking clear definitions can bring the risks of supporting gases that lead to high greenhouse gas (GHG) emissions. This briefing summarizes the findings from a recent paper which provides recommendations for defining renewable gas and low-carbon gas based on life-cycle GHG emissions factors.[1] We suggest thresholds for the most important factors impacting the life-cycle GHG emissions of gases. Example factors are the methane leakage rate and carbon capture rate. Gases that meet these thresholds are much more likely to deliver genuine and large climate benefits compared to gases that remain undefined.

Based on our research, we recommend the following be considered by EU policy makers when crafting policy support for low-carbon gas and renewable gas. These recommendations can also serve the European Parliament and the Council of the European Union as they debate the proposed Directive on Common Rules for the Internal Markets in Renewable and Natural Gases and in Hydrogen (referred to hereafter as the "proposed gas Directive") during the on-going co-decision and trilogue periods.

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1 Yuanrong Zhou and Chelsea Baldino, "Gas definitions for the European Union: Setting thresholds to reduce life-cycle greenhouse gas emissions," (Washington, DC: ICCT, 2022), https://theicct.org/publication/gas-definitions-thresholds-oct22/

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» Require low-carbon gas and renewable gas to meet a GHG reduction requirement based on their life-cycle GHG emissions, by amending Article 2 of the proposed gas Directive.

» Define low-carbon gas and renewable gas as those meeting an 80% life-cycle GHG reduction threshold with a specific comparator, by amending Article 2 of the proposed gas Directive.

» Set thresholds for the key factors that impact a gas's life-cycle GHG emissions to ensure that the gas actually meets the GHG reduction requirement, by amending Article 2 of the proposed gas Directive or by adding an Annex to the proposed gas Directive. Our suggested thresholds are found in Figures 3 and 4.

» Any hydrogen produced from fossil fuels cannot be considered zero-GHG and can only be defined as low-carbon gas under exceptional circumstances.

» Biogas should only be considered low-GHG if produced from wastes and residues.

» Biogas produced from silage maize and stemwood cannot be considered low-GHG.

» Renewable fuels of non-biological origin (RFNBOs), including electrolysis hydrogen, should only be considered low-GHG if made almost entirely from additional renewable electricity in its total production process.

BACKGROUND

Natural gas contributes to significant GHG emissions in the European Union (EU). To reduce the EU's net GHG emissions by at least 55% by 2030 compared to 1990 levels and reach climate neutrality by 2050, EU policy makers look to promote the use of renewable and low-carbon gases.[2] In order to scale up the production of these gases, it is necessary to provide clear, detailed, and consistent definitions to assist the implementation of policies to reduce GHG emissions from the gas sector. Without a clear definition of renewable and low-carbon gases, the EU risks supporting gas pathways that release just as much GHG emissions as fossil fuels.

Several EU policies reference "low-carbon" gases, but none of them provide a definition. These include the EU Taxonomy Regulation, the State Aid for Climate, Environmental Protection and Energy, and the Connecting Europe Facility funding instrument for the energy network.[3] The proposed gas Directive, one of the three proposals under the hydrogen and decarbonized gas market package ("gas package") from December 2021, does provide definitions of renewable gas and low-carbon gas.[4] However, while these definitions can serve as a basis to define gases by different types, it requires more details to properly define the gases for decarbonizing the gas sector.

2 European Commission, "Energy and the Green Deal," (2022), https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/energy-and-green-deal_en.

3 European Commission, "Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the Establishment of a Framework to Facilitate Sustainable Investment, and Amending Regulation (EU) 2019/2088 (Text with EEA Relevance)," 198 OJ L § (2020), http://data.europa.eu/eli/reg/2020/852/oj/eng; European Commission, "Communication from the Commission – Guidelines on State Aid for Climate, Environmental Protection and Energy 2022" (2022), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.C_.2022.080.01.0001.01.ENG&toc=OJ%3AC%3A2022%3A080%3ATOC; European Commission, "About the Connecting Europe Facility," 2022, https://cinea.ec.europa.eu/programmes/connecting-europe-facility/about-connecting-europe-facility_en.

4 The other two policy proposals under the gas package are a Regulation on the Internal Markets for Renewable and Natural Gases and for Hydrogen and a Regulation on Methane Emissions Reduction in the Energy Sector.

THE DEFINITIONS OF RENEWABLE GAS AND LOW-CARBON GAS IN THE PROPOSED GAS DIRECTIVE ARE UNCLEAR

Table 1 presents the definitions of low-carbon gas and renewable gas from Article 2 of the proposed gas Directive, their GHG reduction requirements, and examples of what feedstocks and gas pathways would fall under the proposed definitions. According to the definitions, the source of energy differentiates low-carbon gas from renewable gas. Low-carbon gases are defined as produced from non-renewable feedstocks, such as coal and fossil gas, while renewable gases are made from renewable feedstocks. There are two sub-categories of renewable gas, also differentiated by energy source. One is biogas, including biomethane and hydrogen, that is made from biomass. The other is renewable gas derived from renewable sources other than biomass, which is also known as RFNBOs, as defined in the Article 2 of the recast Renewable Energy Directive (RED II).

Table 1. Definitions of low-carbon hydrogen, low-carbon gas, and renewable gas in the proposed Directive on Common Rules for the Internal Markets in Renewable and Natural Gases and in Hydrogen.

	Definition in Article 2	GHG reduction threshold	Example feedstocks	Example gas pathways
Low-carbon hydrogen	*"...hydrogen the energy content of which is derived from non-renewable sources, which meets a greenhouse gas emission reduction threshold of 70%."*	70%; No specification on the comparator that is used to calculate the GHG reduction	Non-renewable feedstocks, including fossil fuels and nuclear energy	Hydrogen made from non-renewable feedstocks
Low-carbon gas	*"...part of gaseous fuels in recycled carbon fuels as defined in Article 2, point (35) of Directive (EU) 2018/2001, low-carbon hydrogen and synthetic gaseous fuels the energy content of which is derived from low-carbon hydrogen, which meet the greenhouse gas emission reduction threshold of 70%."*	70%; No specification on the comparator that is used to calculate the GHG reduction	Non-renewable feedstocks, including fossil fuels and nuclear energy; Recycled carbon, such as plastics	Hydrogen and synthetic methane made from fossil gas or coal; Synthetic methane made from waste plastics
Renewable gas	*"...biogas as defined in Article 2, point (28) of Directive 2018/2001, including biomethane, and renewable gaseous fuels part of fuels of non-biological origins ('RFNBOs') as defined in Article 2, point (36) of that Directive."*	Article 8 of the proposed Directive: "*Renewable gases shall be certified in accordance with Article 29 and 30 of Directive (EU) 2018/2001*": • 50%–65% GHG reduction for biogas consumed in the transport sector, compared to a 94 gCO_2e/MJ fossil comparator • 70%–80% GHG reduction for biogas consumed in other electricity, heating, and cooling sectors compared to a 94 gCO_2e/MJ fossil comparator • No GHG threshold for RFNBOs.	Biomass; Non-biological renewable energy, such as renewable electricity	Biomethane and hydrogen made from biomass; Hydrogen and synthetic methane made from renewable electricity (RFNBO)

Note: Directive (EU) 2018/2001 refers to the RED II.

There are several issues with these definitions in terms of GHG reduction threshold and its comparator. First, while the proposed gas Directive defines low-carbon gas with a 70% GHG reduction threshold, it is missing a comparator, i.e., a benchmark that is used to calculate that reduction. Consequently, Member States could set different values for the GHG reduction threshold when implementing the policy. In contrast, the RED II has a fossil comparator of 94 grams carbon dioxide equivalent per megajoule (gCO_2e per MJ). By the current design of the proposed gas Directive, this fossil comparator from the RED II would not be applicable to low-carbon gases or RFNBOs, but only to biogases, according to Article 8 of the proposed gas Directive.

Second, Article 2 of the proposed gas Directive does not include a GHG reduction threshold under the definition of renewable gas; instead, Article 8 of the proposed gas Directive references Article 29 and 30 of the RED II for certifying and verifying renewable gases. However, these two referenced articles set GHG reduction thresholds for biogas only and do not include RFNBOs. Specifically, paragraph 10 of Article 29 of the RED II sets a 50%–65% GHG reduction for biogas in the transport sector depending on the installation year, and at least a 70% or 80% reduction for biogas in the electricity, heating, and cooling sectors.[5] Article 25 of the RED II sets a 70% reduction threshold for RFNBOs in the transport sector, but this Article is not referenced in the proposed gas Directive.

The RED II defines RFNBOs only as transport fuels. The revised RED II, released as a part of the Fit for 55 package, changes this definition so it applies to all sectors; if the proposed gas Directive were to reference the revised RED II for the GHG reduction requirement for RFNBOs, it would likely apply to all sectors. However, this is pending Council and Parliament approval.[6]

Finally, setting a GHG reduction threshold is not enough; the success of decarbonization depends on proper evaluation of a gas's life-cycle GHG emissions. Several EU policies, such as the RED II, require that the life-cycle emissions of gases and other fuels be calculated to determine their eligibility for policy support. However, life-cycle GHG accounting is complicated and sometimes erroneous, depending on the methodological choices and numerous data assumptions made by policymakers and certification bodies. As a result, certain pathways in the RED II have been certified with higher GHG savings than they actually produce. While policy makers recognize the adverse climate impacts of food and feed crops due to indirect land use change (ILUC) emissions, these emissions are not accounted for in the RED II; therefore, biomethane from silage maize is able to qualify towards the renewable energy target. To help combat this problem in the transport sector, policy makers capped the amount of food and feed crops that count towards the transport target. The cap serves as an additional sustainability safeguard beyond requiring life-cycle emissions accounting for each fuel pathway. Here, we propose similar sustainability safeguards for the proposed gas Directive. Defining gases by setting thresholds on key life-cycle GHG factors would guarantee the target GHG reductions in the gas sector.

DEFINING GASES BASED ON LIFE-CYCLE GHG EMISSIONS

To properly account for all of a gas's climate impacts, it is imperative to determine their life-cycle GHG emissions. Life-cycle analysis allows a comprehensive understanding of the total potential climate impacts of different gas pathways based on emissions of climate pollutants, including carbon dioxide, methane, and nitrous oxides. Life-cycle well-to-wheel emissions include upstream emissions from feedstock production and transportation, midstream emissions from gas production and processing, and downstream emissions from gas transportation and combustion.

5 Point (d) of paragraph 10 sets the GHG reduction target for biomass fuels, which include biogas.

6 European Commission, "Proposal for a Directive of the European Parliament And Of The Council Amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as Regards the Promotion of Energy from Renewable Sources, and Repealing Council Directive (EU) 2015/652," 2021, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0557.

In a previous life-cycle analysis study,[7] we found that the life-cycle GHG emissions from gases vary significantly, not only among different gas pathways, but even within the same pathway. Figure 1 and Figure 2 show the typical life-cycle GHG emissions from major hydrogen and biomethane pathways in the EU. The error bars in both figures indicate the emissions uncertainties. Hydrogen's GHG intensity can range from negative emissions if made from waste biomass to having higher GHG intensity than fossil gas when made from coal combined with carbon capture and storage (CCS). As the size of the error bars shows, significant variations are seen within the same production pathway due to uncertainties in important factors that have a high impact on GHG emission estimates. For example, the GHG intensity of hydrogen produced from fossil natural gas depends on how much of the fossil gas leaks from drilling equipment and pipes, upstream of the hydrogen production facility, and the amount of CO_2 that can be captured from the hydrogen production process. When variations in these factors within the industry are considered, the GHG intensity of hydrogen produced from fossil natural gas combined with CCS varies from 7 to 92 gCO_2e per MJ (Figure 1). While gases on the low end of this spectrum may be considered "low-GHG", those on the high end certainly would not be. This exercise shows that defining gases as renewable gas or low-carbon gas based solely on their energy source is not an effective way to ensure climate benefits.

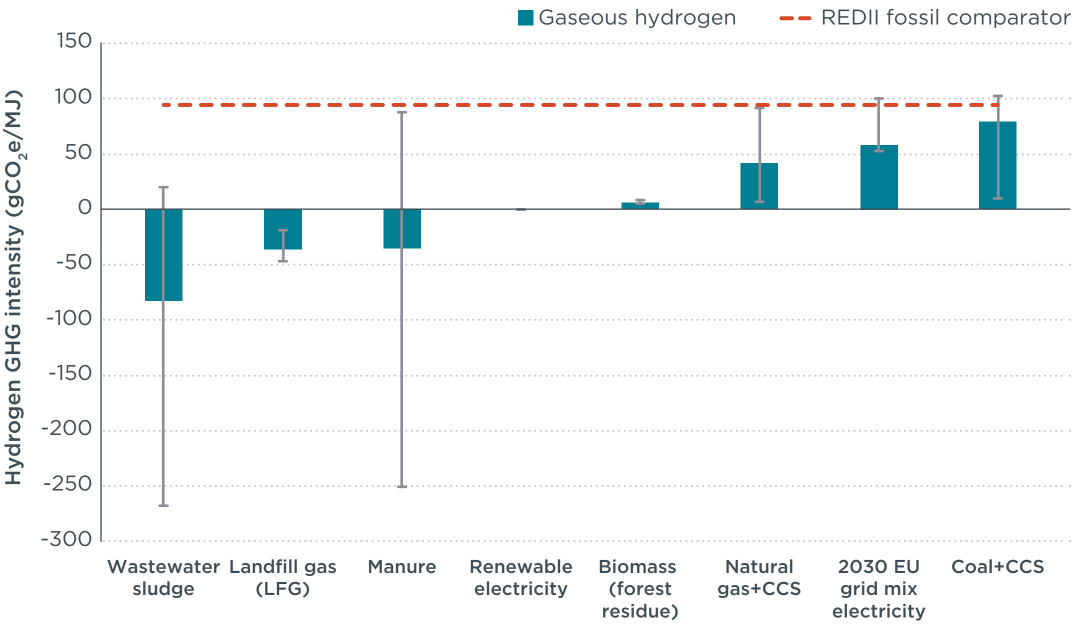

Figure 1. Life-cycle GHG emissions from hydrogen in the EU.

7 Yuanrong Zhou, Diana Swidler, Stephanie Searle, and Chelsea Baldino, "Life-Cycle Greenhouse Gas Emissions of Biomethane and Hydrogen Pathways in the European Union," (Washington, D.C.: ICCT, 2021), https://theicct.org/publication/life-cycle-greenhouse-gas-emissions-of-biomethane-and-hydrogen-pathways-in-the-european-union/.

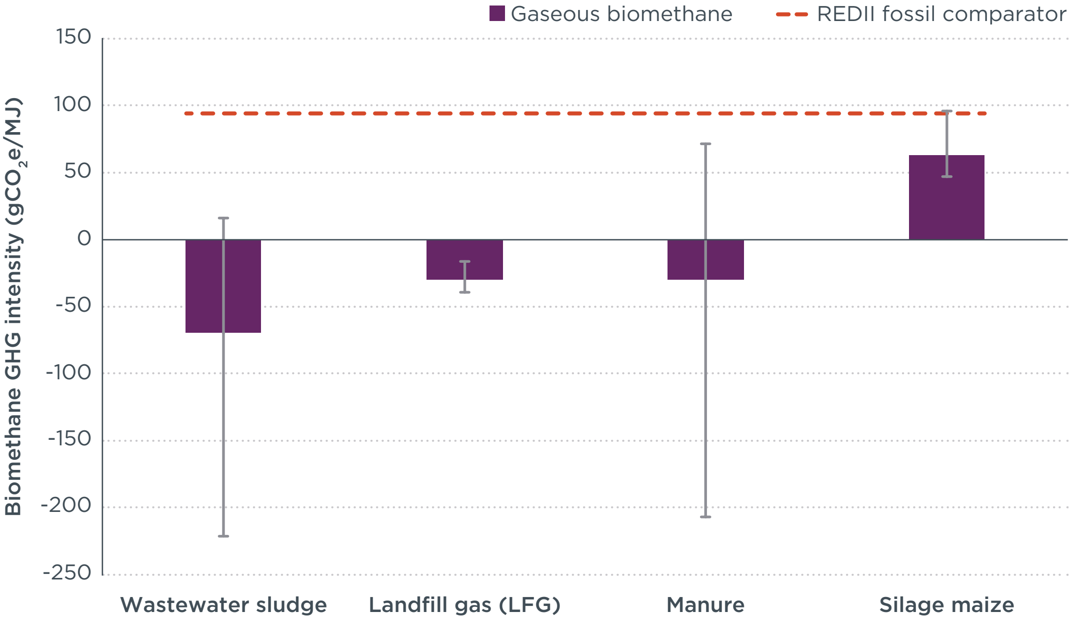

Figure 2. Life-cycle GHG emissions from biomethane in the EU.

We propose that for any gas to be considered as "low-GHG", no matter it's renewable or non-renewable, it must deliver an 80% GHG reduction requirement relative to a specific comparator, such as the RED II fossil comparator (94 gCO_2e/MJ). Key factors that must be considered in order for major gas pathways to deliver 80% GHG savings are shown in Table 2. For example, the process of making hydrogen from fossil fuels can generate a substantial amount of CO_2 and the portion of that CO_2 being captured would impact whether the hydrogen produced can meet the 80% GHG reduction requirement.

Table 2. Key life-cycle GHG factors for hydrogen and biomethane.

Gas pathway	Key factors	Explanation
RFNBOs, such as electrolysis hydrogen	Share of renewable electricity as the energy input	Electrolysis uses electricity to split water into hydrogen. That electricity could be renewable (e.g., wind, solar) or fossil-based (e.g., coal, fossil natural gas)
Hydrogen from fossil gas SMR + CCS	Carbon capture rate at hydrogen production plant	The process of making hydrogen from fossil natural gas using steam methane reforming releases large amounts of CO_2. That CO_2 can be captured at the plant and sequestered underground to stop its release to the atmosphere.
	Upstream methane leakage rate	Methane can leak from fossil gas drilling and pipes. The methane leakage happens upstream of hydrogen production has a significant impact on life-cycle emissions from hydrogen made from fossil gas.
Hydrogen from coal gasification + CCS	Carbon capture rate at hydrogen production plant	The process of making hydrogen from coal using gasification releases large amounts of CO_2. That CO_2 can be captured at the plant and sequestered underground to stop its release to the atmosphere.
Hydrogen and biomethane from biomass gasification or anaerobic digestion	Biomass source	Biogases can be produced from different biomasses, such as food crops and waste biomass. These biomasses differ significantly in their climate impacts.
	Methane leakage rate during biogas production	Methane can leak onsite at biogas facilities and can contribute significantly to emission intensity.

Notes: SMR = steam methane reforming. CCS = carbon capture and storage.

The selection of the comparator is important for determining GHG reduction thresholds. The comparator we use to define gases in this paper from the RED II (94 gCO_2e/MJ) is based on the life-cycle GHG emissions of gasoline and diesel. An alternative would be to use the GHG intensity of fossil natural gas as a comparator for calculating the GHG savings of low-carbon and renewable gases. Such a fossil gas comparator has not been established in EU policies, although the Council Directive 2015/652 provides a GHG intensity of 65.9 gCO_2e per MJ for fossil gas.[8] From the policy design and implementation perspective, it might be easier to use a consistent comparator across EU policies; we reference the fossil comparator in the RED II in the related study.[9] However, since this fossil comparator is higher than the GHG intensity of fossil gas, we set a higher GHG reduction threshold of 80% as opposed to the 70% threshold in the proposed gas Directive. This produces a life-cycle GHG emissions threshold of 19 gCO_2e per MJ, which is similar to a 70% reduction from a more gas-specific fossil comparator (Table 3). Further, the thresholds we derive for each pathway based on an 80% GHG reduction requirement would still be relevant were a 70% GHG reduction requirement to be used instead. We also include a 100% GHG reduction "zero-GHG" category to highlight the gas pathways that can achieve the deepest decarbonization and best support the EU in reaching net decarbonization by 2050.

Table 3. Life-cycle GHG intensity based on different comparators and GHG reduction thresholds.

Life-cycle GHG intensity (gCO_2e per MJ)	Fossil gas comparator (65.9 gCO_2e per MJ)	RED II comparator (94 gCO_2e per MJ)
70% GHG reduction threshold	19.8	28.2
80% GHG reduction threshold	13.2	18.8

Note: The fossil gas comparator is from the Council Directive 2015/652.

PROPOSED GAS DEFINITIONS

Figure 3 and Figure 4 summarizes our proposed criteria for defining renewable gas and low-carbon gas, respectively, as "zero-GHG" and "low-GHG", based on the conditions that would result in 100% or 80% GHG reductions, respectively, from the fossil comparator of the RED II (94 gCO_2e/MJ). We propose that gas from renewable sources must also meet at least the GHG reduction criteria for "low-GHG" to be considered renewable gas. Detailed methodology of how these thresholds are derived can be found in the related paper.[10]

8 Council Directive (EU) 2015/652 of 20 April 2015 laying down calculation methods and reporting requirements pursuant to Directive 98/70/EC of the European Parliament and of the Council relating to the quality of petrol and diesel fuels

9 "Gas definitions for the European Union: Setting thresholds to reduce life-cycle greenhouse gas emissions."

10 Zhou and Baldino, "Gas definitions for the European Union: Setting thresholds to reduce life-cycle greenhouse gas emissions."

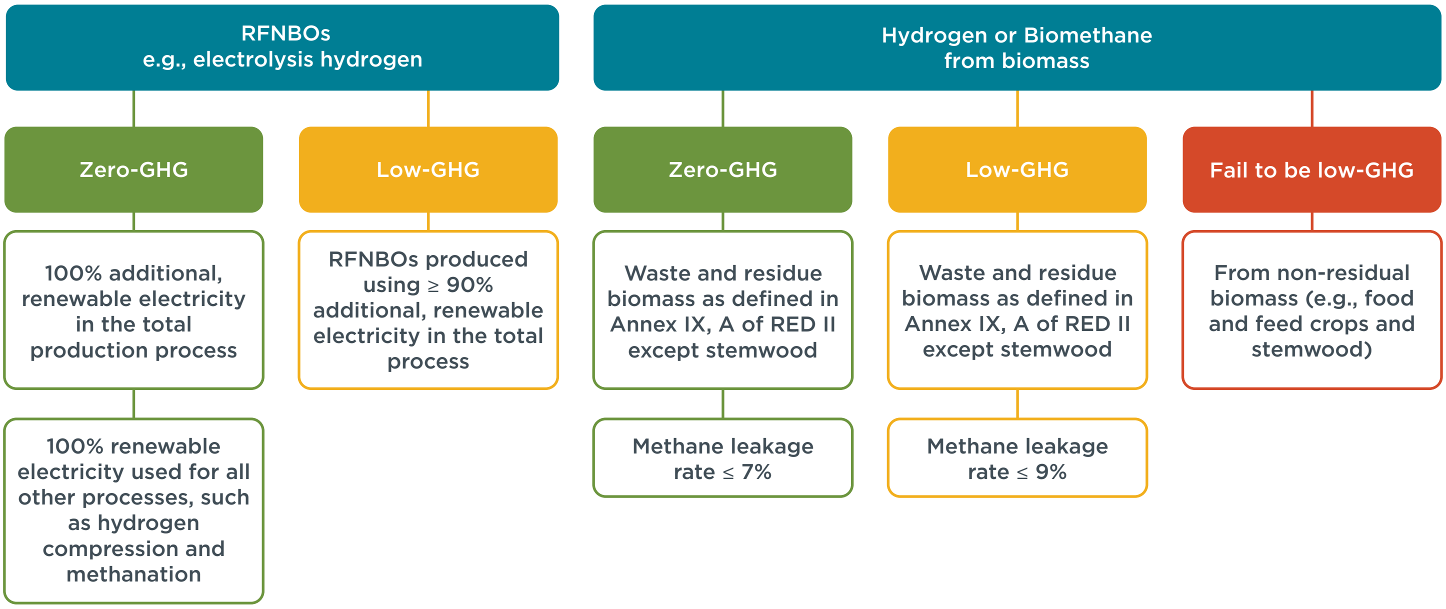

Figure 3. Definitions of renewable gases based on life-cycle GHG thresholds of zero-GHG (100% GHG reduction) and low-GHG (80% GHG reduction). The fossil comparator in the RED II (94 gCO_2e/MJ) is used for GHG reductions. Renewable electricity is for electricity produced from near-zero GHG electricity, which we assume here to be solar and wind. For the hydrogen and biomethane pathways produced from waste and residues, we present the lowest methane leakage rates.

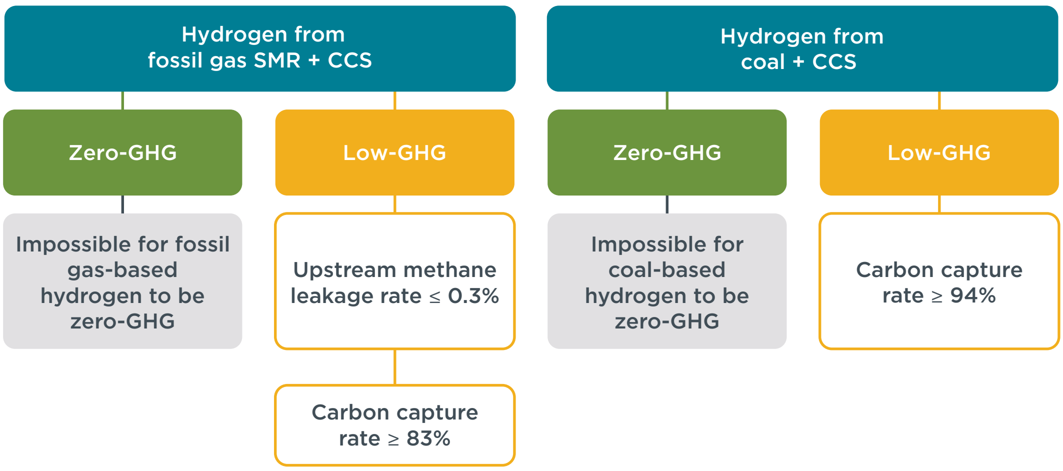

Figure 4. Definitions of low-carbon gases based on life-cycle GHG thresholds of zero-GHG (100% GHG reduction) and low-GHG (80% GHG reduction). The fossil comparator in the RED II (94 gCO_2e/MJ) is used for GHG reductions.

We find that hydrogen made from fossil gas or coal cannot achieve zero GHG emissions. It would also be difficult for fossil-based hydrogen to be defined as low-carbon gas with an 80% GHG reduction requirement. This is because the current technology and economics only allow 55% of CO_2 generated from the hydrogen plant to be captured,[11] which is significantly lower than the 84% (fossil gas-based hydrogen) or 95% (coal-based hydrogen) carbon capture rates required to reach an 80% GHG reduction.

11 Christine Kandziora, Ken Lamb, and Goutam Shahani, "CO_2 Capture from Steam Methane Reformers - Understanding the Options," *Ammonia Technical Manual*, 2014, 10.

To be considered low-GHG, RFNBOs such as electrolysis hydrogen must be produced using at least 90% additional renewable electricity sources such as wind and solar in its total production process. Almost all Member States would fail to meet an 80% GHG reduction threshold if straight grid electricity is used for producing electrolysis hydrogen. For RFNBOs to be defined as zero-GHG emission, 100% additional renewable electricity must be used throughout its life cycle, including the total processes at the production plant and other downstream processes such as hydrogen compression. It is necessary that the renewable electricity used in both cases is additional and not displaced from other uses that would likely be replaced by fossil fuels. To tackle this complex and crucial issue, the European Commission (EC) has proposed a delegated regulation to the RED II with detailed rules on additionality for RFNBOs.[12] At the time of writing, it is unclear whether this delegated regulation will remain in the RED II.

Methane leakage is a key GHG parameter for gas pathways involving fossil gas and biomethane. For hydrogen made from fossil gas to be defined as low-carbon with an 80% GHG reduction, in addition to the 84% carbon capture rate, the total upstream leakage rate from fossil gas extraction, processing, and transportation must be less than 0.3%. To put this into perspective, there is evidence methane leakage along the fossil gas supply chain can be around 0.2%–3% and may even be up to 20% in some cases.[13] To ensure gas production meets the methane leakage thresholds, it is necessary to have robust monitoring, measuring, and tracking of methane leakage. The proposed Regulation on Methane Emissions Reduction in the Energy Sector under the gas package sets rules for the energy sector, particularly for fossil gas and coal sectors, on methane emissions quantification, tracking, and reduction. Once implemented, the required measurements and database on methane emissions maintained under this Regulation could enable policy makers to identify gas supply chains that meet our proposed methane leakage limit to be compatible with a low-carbon gas pathway.

For biogas pathways, feedstock type is another critical parameter for determining GHG emissions in addition to methane leakage. When stemwood and food and feed crops such as silage maize are used for biogas production, the biogas cannot be considered low-GHG. Although silage maize is a common feedstock for biomethane production in the EU, the fact it is a food and feed crop means it is associated with substantial GHG emissions from land use change, in addition to food price impacts.[14] Using stemwood for biogas production depletes forest carbon stocks and results in higher net GHG emissions than using fossil fuels.[15] This is true despite the fact that pulp-quality stemwood is included in the category “other ligno-cellulosic material” in Annex IX, A of the RED II and receives additional support under the RED II.

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12 European Commission, “Commission Delegated Regulation Supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council,” (2022), https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/7046068-Production-of-renewable-transport-fuels-share-of-renewable-electricity-requirements-_en.

13 IEA, “Optimising Russian Natural Gas – Analysis,” (2006), https://www.iea.org/reports/optimising-russian-natural-gas; Robert W. Howarth, Renee Santoro, and Anthony Ingraffea, “Methane and the Greenhouse-Gas Footprint of Natural Gas from Shale Formations: A Letter,” *Climatic Change* 106, no. 4 (June 2011): 679–90, https://doi.org/10.1007/s10584-011-0061-5; Paul Balcombe, “Methane and CO_2 Emissions from the Natural Gas Supply Chain,” (Sustainable Gas Institute, 2015); Robert W. Howarth, “Methane Emissions and Climatic Warming Risk from Hydraulic Fracturing and Shale Gas Development: Implications for Policy,” *Energy and Emission Control Technologies* 3 (October 8, 2015): 45–54, https://doi.org/10.2147/EECT.S61539; Ramón A. Alvarez et al., “Assessment of Methane Emissions from the U.S. Oil and Gas Supply Chain,” *Science* 361, no. 6398 (July 13, 2018): 186–88, https://doi.org/10.1126/science.aar7204; Robert W. Howarth and Mark Z. Jacobson, “How Green Is Blue Hydrogen?,” *Energy Science & Engineering* 9, no. 10 (October 2021): 1676–87, https://doi.org/10.1002/ese3.956.

14 European Commission, “The Land Use Change Impact of Biofuels Consumed in the EU,” (2015,) https://ec.europa.eu/energy/sites/ener/files/documents/Final%20Report_GLOBIOM_publication.pdf.

15 Agostini Alessandro, Jacopo Guintoli, and Boulamanti Aikaterini, *Carbon Accounting of Forest Bioenergy: Conclusions and Recommendations from a Critical Literature Review* (Joint Research Centre, 2014), https://data.europa.eu/doi/10.2788/29442.

Only biogas produced from waste and residue biomass can be considered zero- or low-GHG emissions. The majority waste and residue feedstocks are defined in Annex IX, A of the RED II, including agricultural and forestry residues, animal manure, and wastewater sludge. However, while waste feedstocks can provide deep decarbonization, their usage is limited by feedstock availability and subject to intersectoral competition with biofuels for the hard-to-decarbonize aviation and marine sectors, as well as the power sector.[16]

To label gas as renewable or low-carbon, a robust certification system with clear and accurate labeling will be crucial. Paragraph 5 of Annex I of the proposed gas Directive requires gas suppliers to disclose CO_2 emissions information to the end users, but it does not provide any further details, such as how gas suppliers should estimate the emissions. In addition to ambiguity, this rule does not include methane and nitrous oxide emissions, which are potent GHGs that contribute significantly to the gas sector emissions. In order to properly define low-carbon gas and renewable gas, it is necessary to certify them based on life-cycle GHG emissions, especially in regards to the GHG factor thresholds defined in this paper.

Guarantees of origin (GOs), energy certificates issued by a third-party verifier that provide disclosure and transparency regarding the sources of the energy supplied to final consumers, is a well-developed certification concept that could be used to define gases in line with the proposed gas Directive's definitions. At present, GOs have mainly only been applied in the electricity market. Standards concerning the adoption of GOs in the gas market are still in the initial stages. A standard with clear rules and detailed guidance for the industry is crucial for proper and compatible use of GOs among different gas suppliers and consumers.

16 Bryan Comer, Jane O'Malley, Liudmila Osipova, and Nikita Pavlenko, "Comparing the Future Demand for, Supply of, and Life-Cycle Emissions from Bio, Synthetic, and Fossil LNG Marine Fuels in the European Union," (Washington, DC: ICCT, 2022), https://theicct.org/publication/lng-marine-fuel-sep22/.