www.theicct.org

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

BRIEFING

MAY 2019

Gas definitions for the European Union

As part of its commitment to mitigate climate change and limit global warming to below 2°C, the European Union (EU) proposed an ambitious nationally determined contribution to cut its domestic greenhouse gas (GHG) emissions by at least 40% below 1990 levels by 2030. The European Commission has also outlined a vision for a climate-neutral economy by 2050.[1] The EU has made progress in reducing emissions through its limited participation in the Kyoto protocol, but the region still requires substantial changes to its energy and transportation systems in order to reach its 2030 target and ensure decarbonization by 2050. While natural gas has thus far played a role in providing flexible, responsive electricity and displacing more carbon-intensive coal power, the EU must identify and deploy low-carbon alternatives in the coming years. This can include low-carbon gas, but also other forms of energy, including greater penetration of renewable electricity on the grid, electric vehicles in transport, and deployment of flexible, smart grid technologies.

In concert with other solutions, the deployment of ultralow-carbon fuels with meaningful reductions in GHG emissions can guide the EU towards its 2050 goal of a decarbonized energy sector. To date, the terminology surrounding potential solutions for decarbonizing Europe's gas sector can be confusing, as various actors refer to possible alternatives to natural gas as "green," "renewable," "zero-carbon," "low carbon", or "decarbonized" almost interchangeably. A coherent debate on the role of gas in the goal of net zero GHG emissions in 2050 is not possible without a common understanding of which specific strategies and pathways must be promoted. To that end, this document discusses key terms related to gas in the context of energy policy and climate change mitigation goals in the European Union. This paper proposes a method of categorizing gas sources based on their GHG emissions intensity and illustrates how these categories can be used to refer to gas from different sources.

---

[1] European Commission. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee, the Committee of the Regions and the European Investment Bank. 2018. Com (2018) 773. https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_en.pdf

---

Prepared by Stephanie Searle and Nikita Pavlenko

DEFINING THE CLIMATE PERFORMANCE OF VARIOUS GAS SOURCES

Decarbonizing the EU's gas sector requires identifying and deploying the best-performing sources of alternative gas; however, the wide variety of feedstocks and conversion pathways for producing gases necessitates more nuanced terms than "renewable" or "sustainable" to characterize their suitability for long-term decarbonization. For example, to be "renewable," a gas source must simply regenerate on a human timescale—this does not necessarily ensure positive climate performance. A given gas source's climate impact can vary considerably among both renewable and fossil sources depending on the feedstock or conversion pathway. To evaluate a gas's impact on the climate, we must assess its life-cycle GHG emissions or carbon intensity (CI). While broad categories of gases such as methane (CH_4) have clear and consistent combustion emissions, methane's CI is determined by a variety of factors across its life-cycle, including feedstock production, processing and land-use change impacts.[2]

The feedstock used to produce a gas typically determines that gas's cradle-to-grave GHG emissions. For example, biomethane can have very different climate impacts depending on its feedstock. Biomethane made from waste feedstocks, such as dairy manure, can have negative lifecycle GHG emissions because converting this feedstock into biomethane avoids high emissions of methane to the atmosphere that would normally occur during natural decomposition at farms.[3] In contrast, biomethane produced from the anaerobic digestion of purpose-grown crops, such as silage maize, only partly reduces emissions relative to natural gas, due to the upstream energy and resources used to grow crops. Furthermore, increasing the demand for food and feed crops leads to global agricultural expansion, and the resulting land conversion releases substantial amounts of carbon stored in soils and existing biomass.[4] When land-use change emissions are taken into account, biomethane from food and feed crops can be expected to deliver very limited, if any, net GHG reductions compared to natural gas.

The technology and operating parameters for gas production processes can also play a large role in determining the final carbon intensity for a given source of gas. Methane leakage from gas production facilities and transport infrastructure have a large impact on any gas pathway's lifecycle GHG performance as methane is a potent climate forcer. Even small rates of leakage from a poorly designed or maintained facility can turn an otherwise low-GHG gas pathway into a net climate polluter. For pathways that rely on carbon capture or upstream carbon capture and sequestration (CCS), assumptions regarding the capture rate and the permanence of CO_2 storage dictate the GHG savings for a given process. For example, implementing CCS for point-source emissions at the combustion site may be more viable than capturing GHG emissions at the varied, small points upstream during material extraction, transport and processing.

Rather than characterizing broad categories of fuels, such as biomethane and hydrogen, as either "good" or "bad" for the purposes of decarbonization, more nuanced language is needed which takes into account the climate performance both across and within different gas production systems. A full, life-cycle analysis is necessary to properly evaluate the climate impacts of a specific gas producer.

---

[2] Chelsea Baldino, Nikita Pavlenko, & Stephanie Searle, *The potential for low carbon renewable methane in heat, power, and transport in the European Union*, (ICCT: Washington, DC, 2018). https://www.theicct.org/sites/default/files/publications/Biogas_potential_FR_IT_ES_20181109.pdf

[3] Ibid.

[4] Hugo Valin, Daan Peters, Maarten van den Berg, Stefan Frank, Petr Havlik, Nicklas Forsell, & Carlo Hamelinck, *The land use change impact of biofuels consumed in the EU: Quantification of area and greenhouse gas impacts*, (Ecofys: Utrect, 2015) https://ec.europa.eu/energy/sites/ener/files/documents/Final Report_GLOBIOM_publication.pdf

To assess the environmental performance of gas, the different sources can be characterized into two different categories. First , gas sources can be classified as renewable or fossil. A gas source is **renewable** if it is naturally regenerating on a human timescale. Renewable energy includes wind, solar, geothermal, tidal, and ambient energy, hydropower, biomass, and biomethane. Regeneration is an important component of long-term sustainability, as it ensures that these resources can be used to meet the needs of the present without compromising future demands. However, not all renewable energy sources necessarily generate substantial carbon savings relative to fossil fuel-derived gas, and vice-versa. In contrast to renewable sources of gas, fossil gas is a natural gas or an energy-carrying gas produced in a process that utilizes hydrocarbons originating from beneath the earth's surface, such as coal, natural gas, or petroleum, as a chemical feedstock or a primary energy source.

Next, the gas source can be categorized on the basis of its life-cycle GHG emissions. This includes the total cradle-to-grave emissions attributable to producing and consuming a gas source, normalized by its energy content measured in grams CO_2 per MJ of gas. We use "GHG" instead of "carbon" to encompass a broader range of climate forcers because the net climate impact of various GHGs is not necessarily correlated with the amount of carbon—for example, methane (CH_4) is a much more potent climate forcer than carbon dioxide (CO_2).

The climate performance of different gas sources can be separated into several tiers:

- **High-GHG**: Gases with a life-cycle GHG intensity of 30% or higher than business-as-usual natural gas can be classified as high-GHG. This includes natural gas and hydrogen produced from natural gas without effective carbon capture and storage (CCS), and synthetic gases produced from fossil-derived electricity. Some renewable gas or biomethane pathways can also be high-GHG if they cause high land-use change or other indirect emissions. This category of gas likely needs to be phased out in the near future in order to meet Europe's climate targets.
- **Low-GHG:** Gases that reduce lifecycle GHG emissions by a substantial degree compared to business-as-usual natural gas can be classified as low-GHG. For example, the Renewable Energy Directive 2018/2001 requires renewable power-to-methane to reduce GHG emissions by 70% compared to fossil fuels. Low-GHG energy sources meaningfully reduce overall climate impacts compared to business-as-usual fossil fuels. When assessing lifecycle GHG emissions, it is important to include direct and indirect emissions from land-use change, displacement of feedstocks from other uses, and electricity grid impacts in the calculation of lifecycle GHG performance.
- **GHG-neutral:** Gases with zero net GHG emissions can be classified as GHG-neutral. GHG-neutral energy sources have either no impact or a beneficial impact on climate change compared to not using the energy source at all. This includes pathways with negative GHG emissions on a life-cycle basis. For example, if avoided methane emissions upstream more than counteract processing & combustion emissions, the gas could be classified as GHG-neutral.

Most gas pathways, whether fossil or renewable, can be classified as high-GHG, low-GHG, or GHG-neutral depending on how they are implemented, exactly what feedstocks they use, and how efficient their processes are. A full lifecycle analysis is necessary for all specific pathways and producers to categorize their GHG performance. Table 1 summarizes how these definitions can apply to gas from different sources, and provides a few specific examples.

Table 1: Summary of gas types according to key definitions of environmental performance

	High-GHG	Low-GHG	GHG-neutral
Fossil gas	**Natural gas** produced from both conventional and unconventional sources **Fossil gas** produced through the gasification of fossil fuels such as coal or petroleum coke **Hydrogen** or **synthetic methane** produced from electricity bearing upstream GHG emissions without carbon capture and storage (CCS)	**Hydrogen** produced from natural gas in a process that captures most supply chain and process CO_2 through CCS **Synthetic methane** produced from fossil-derived electricity with CCS capturing most CO_2 from combustion	**Hydrogen** produced from natural gas in a process that captures all supply chain GHGs and process CO_2 through CCS **Hydrogen** or **synthetic methane** produced from fossil-derived electricity with CCS capturing all CO_2 from combustion and supply chain emissions
Renewable gas	**Biomethane** produced from purpose grown-crops with high land-use change emissions	**Hydrogen** or **synthetic methane** produced from additional low-GHG electricity **Biomethane** produced from wastes or purpose-grown crops on low-carbon stock land with low methane leakage	**Hydrogen** or **synthetic methane** produced from additional or excess renewables electricity with zero net GHG emissions **Biomethane** produced from wastes whose avoided methane emissions offset or exceed production and combustion emissions

Note: The examples of specific production processes categorized in Table 1 are not intended to be exhaustive, but rather, to illustrate different production pathways could fit in multiple categories, depending on the specific feedstocks and conversion process used by a given producer.

While gas from fossil sources is categorized as non-renewable, Table 1 illustrates how the categorization for fossil gases by GHG performance can vary substantially depending on the specifics of how a given fossil-derived gas is produced. At the upper end of the range, conventional natural gas and fossil gases produced via unconventional processes, such as the gasification of petroleum coke, are categorized as high-GHG. Likewise, hydrogen produced via steam methane reforming using natural gas without any CCS, referred to as grey hydrogen, is also a high-GHG gas pathway. At the extreme lower end, hydrogen produced via steam methane reforming or the combustion of natural gas could plausibly be classified as GHG-neutral if all the emitted CO_2 is robustly sequestered long-term, and upstream emissions from the supply chain are either zero or offset by another source of carbon sequestration. This would likely require exceptional efforts, particularly to ensure zero upstream emissions, and it is not yet clear whether any GHG-neutral fossil pathways are technically feasible. Hydrogen could be categorized as low-GHG when all or part of the steam reforming emissions are captured and sequestered, but some upstream emissions remain.

Gas produced via electrolysis, including power-to-methane and hydrogen, can also fit within any combination of the above categories, depending on the feedstock used and the operating parameters of the conversion process in question. The electrolysis process utilizes electricity to break down water (H_2O) into hydrogen (H_2) and oxygen (O_2) gases, for either direct use as hydrogen (electrolysis-to-hydrogen) or in combination with captured carbon to generate synthetic methane (power-to-methane). The source of electricity for the electrolysis process not only determines if the pathway is renewable, but also plays a large role in determining its GHG impact. This is because the conversion rate between upstream electricity and finished gas magnifies the emissions impact of the electricity.[5] For example, the use of additional or excess zero-GHG electricity from wind and solar to produce hydrogen for electrolysis, or green hydrogen, is a renewable, GHG-neutral pathway. However, that same process utilizing conventional fossil-powered electricity in the absence of CCS will be neither renewable nor GHG-neutral. As with fossil gases, the production of hydrogen or synthetic methane using electrolysis utilizing conventional power with CCS could place those fuels in the low-GHG category, but they would be non-renewable. It is critical to ensure that the electricity used to power gas electrolysis pathways comes from additional renewable electricity, rather than renewable electricity diverted from other uses. Without this safeguard in place, the electrolysis process could generate indirect emissions from the fossil-powered electricity used to replace the diverted renewable energy, greatly increasing the total GHG emissions attributable to that gas pathway.[6]

In order for any fossil pathway to be categorized as low-GHG, CCS will be necessary during fuel production. In addition, the captured carbon can only be considered fully sequestered if the operator ensures a high degree of permanence and low risk for the sequestration site. For example, in California's CCS protocol, operators must develop an extensive risk assessment for each injection site, including testing for faults, conducting fluid and atmospheric modeling, and complying with strict operating requirements for pressure management and leak mitigation.[7]

In order to properly account for carbon capture, it is important to draw a distinction between CCS and carbon capture and utilization (CCU). In CCU, captured carbon is utilized for a given fuel production process or end-use. In this case, CO_2 from a fossil fuel power plant or flue gases from a steel mill may be utilized as an input for synthetic methane production. It is critical that policymakers ensure that the carbon storage from CCU is only attributed to one product within the product system in order to prevent double-claiming of the benefits. For example, captured carbon from an existing coal combustion facility may be used for synthetic methane, but if the climate benefit of using a waste CO_2 feedstock is attributed to the synthetic methane in lifecycle accounting, the upstream coal electricity production should not also be credited and counted as low-carbon. It is common practice in life-cycle analysis to attribute the climate benefit of using captured CO_2 on the product side, such as the synthetic methane in the example above. Therefore, CCU should not count for reducing climate impacts from burning natural gas or SMR.

For the purposes of life-cycle analysis accounting, the source of CO_2 does not influence the calculation of GHG emissions for a given pathway, so long as that CO_2 was not produced purposefully for the CCU process. The climate benefit of producing synthetic methane using CO_2 from direct air capture is thus identical to that of using waste CO_2 from a coal plant, as long as the coal plant could be expected to operate regardless of CO_2 sales. In the long-term, it is possible that policy tools may be necessary to ensure that CCU does not perpetuate the use of fossil fuels. If all industrial CO_2 emissions are phased out in the future or claimed by other circular economy processes, all CCU must utilize CO_2 from direct air capture to continue delivering climate benefits.

Biomethane derived entirely from biomass feedstocks, can be categorized as entirely renewable. However, as stated above, biomethane can have entirely different GHG impacts depending on the feedstock in question. Waste-derived biomethane associated

---

[5] Searle, S., and Christensen, A., *Decarbonization Potential of Electrofuels in the European Union*, (ICCT: Washington, DC, 2018), https://www.theicct.org/sites/default/files/publications/Electrofuels_Decarbonization_EU_20180920.pdf

[6] Ibid.

[7] California Air Resources Board, "Carbon Capture and Sequestration Protocol under the Low-Carbon Fuel Standard," (2019), https://www.arb.ca.gov/fuels/lcfs/ccs_protocol_010919.pdf

with high avoided methane emissions is often classified as either low-GHG or GHG-neutral, whereas biomethane produced from purpose-grown crops bears a higher GHG impact, and can be either low-GHG or even high-GHG depending on the crop in question. For example, the cultivation of silage maize for biomethane production in the EU can be expected to displace food production on cropland and thereby cause indirect land-use change. The indirect land-use change emissions from silage maize of 17 gCO2e per MJ of biomethane, in conjunction with cultivation and processing emissions, pushes that gas source into the high-GHG category.[8] Within a given combination of feedstock and process, factors such as the degree of methane leaks for a given facility may further influence the GHG categorization for that producer.

EXAMPLE DETAILED GAS DEFINITIONS

With such a wide variety of potential gas production pathways, it is challenging to categorize different types of gas according to their climate performance in a meaningful way. Examples are provided below of detailed definitions of various types of gas with an aim to address both basic differences in gas types and GHG impacts in the context of existing EU policy.

Biogas: Gaseous fuels produced from biomass, as defined in point 24 of Article 2 of Directive (EU) 2018/2001, including energy-carrying gas that is primarily methane and mixtures that are partially methane produced from biomass feedstocks through anaerobic digestion, gasification, or other processes.

Fossil gas: Natural gas or an energy-carrying gas produced in a process that utilizes hydrocarbons originating from beneath the earth's surface, such as coal, natural gas, or petroleum, as a chemical feedstock or a primary energy source.

GHG-neutral biogas: Low-carbon biogas that reduces lifecycle greenhouse gas emissions by at least 100% following combustion compared to natural gas, including upstream greenhouse gas emissions from direct and indirect land-use change and methane leakage.

GHG-neutral gas: Carbon-neutral biogas, carbon-neutral methane and carbon-neutral hydrogen.

GHG-neutral hydrogen: Low-carbon hydrogen that reduces lifecycle greenhouse gas emissions by at least 100% following combustion compared to natural gas, including upstream greenhouse gas emissions from direct and indirect land use change, methane leakage, and indirect changes to electricity production.

GHG-neutral methane: Low-carbon methane that reduces lifecycle greenhouse gas emissions by at least 100% following combustion compared to natural gas, including upstream greenhouse gas emissions from direct and indirect land-use change, methane leakage, and indirect changes to electricity production.

---

[8] Hugo Valin, Daan Peters, Maarten van den Berg, Stefan Frank, Petr Havlik, Nicklas Forsell, & Carlo Hamelinck, *The land use change impact of biofuels consumed in the EU: Quantification of area and greenhouse gas impacts*, (Ecofys: Utrect, 2015) https://ec.europa.eu/energy/sites/ener/files/documents/Final Report_GLOBIOM_publication.pdf

High-GHG biogas: Biogas that does not reduce lifecycle greenhouse gas emissions by at least 70% following combustion compared to natural gas, including upstream greenhouse gas emissions from direct and indirect land use change and methane leakage.

High-GHG hydrogen: Gas containing primarily hydrogen that does not reduce lifecycle greenhouse gas emissions, including upstream greenhouse gas emissions from direct and indirect land-use change, methane leakage, and indirect changes to electricity production, by at least 70% following combustion compared to natural gas, and hydrogen produced using food and feed crops, as defined in point 40 of Article 2 of Directive(EU) 2018/2001, or forest-derived biomass, excepting tree tops and small branches, as either a chemical feedstock or a process energy source.

High-GHG methane: Gas containing primarily methane that does not reduce lifecycle greenhouse gas emissions, including upstream greenhouse gas emissions from direct and indirect land-use change, methane leakage, and indirect changes to electricity production, by at least 70% following combustion compared to natural gas, and methane produced using food and feed crops, as defined in point 40 of Article 2 of Directive(EU) 2018/2001, or forest-derived biomass, excepting tree tops and small branches, as either a chemical feedstock or a process energy source.

Low-GHG biogas: Biogas that reduces lifecycle greenhouse gas emissions by at least 70% following combustion compared to natural gas, including upstream greenhouse gas emissions from direct and indirect land-use change and methane leakage.

Low-GHG gas: Low-carbon biogas, methane, and low-carbon hydrogen.

Low-GHG hydrogen: Gas containing primarily hydrogen that reduces lifecycle greenhouse gas emissions by at least 70% following combustion compared to natural gas, including upstream greenhouse gas emissions from direct and indirect land-use change, methane leakage, and indirect changes to electricity production, including renewable hydrogen, hydrogen derived from waste as defined in point 23 of Article 2 of Directive(EU) 2018/2001, hydrogen produced from other low-GHG electricity sources, and hydrogen derived from fossil fuels in a process that reduces greenhouse gas emissions for example through CO_2 capture and sequestration, provided the permanence of CO_2 storage can be ensured and verified, and excluding hydrogen produced using food and feed crops, as defined in point 40 of Article 2 of Directive(EU) 2018/2001, or forest-derived biomass, excepting tree tops and small branches, as either a chemical feedstock or a process energy source.

Low-GHG methane: Gas containing primarily methane that reduces lifecycle greenhouse gas emissions by at least 70% following combustion compared to natural gas, including upstream greenhouse gas emissions from direct and indirect land use change, methane leakage, and indirect changes to electricity production, including renewable methane, methane derived from waste as defined in point 23 of Article 2 of Directive(EU) 2018/2001, methane produced from other low-GHG electricity sources, and fossil gas that reduces greenhouse gas emissions, for example through CO_2 capture and sequestration, provided the permanence of CO_2 storage can be ensured and verified, and excluding gas produced using food and feed crops, as defined in point 40 of Article 2 of Directive(EU) 2018/2001, or forest-derived biomass, excepting tree tops and small branches, as either a chemical feedstock or a process energy source.

Natural gas: Naturally-occurring gas, mostly composed of methane, originating from beneath the earth's surface containing a high proportion of combustible gaseous hydrocarbons.

Renewable gas: Biogas, renewable methane and renewable hydrogen.

Renewable hydrogen: Gas containing primarily hydrogen produced from biomass, as defined in point 24 of Article 2 of Directive (EU) 2018/2001, or from a process using renewable energy as defined in point 1 of Article 2 of Directive (EU) 2018/2001 as the sole energy-carrying input.

Renewable methane: Gas containing primarily methane produced from biomass, as defined in point 24 of Article 2 of Directive (EU) 2018/2001, or from a process using renewable energy as defined in point 1 of Article 2 of Directive (EU) 2018/2001 as the sole energy-carrying input, including methane produced from renewable electricity and waste or ambient CO_2.

Syngas (i.e., synthesis gas): A gas mixture primarily containing a high proportion of carbon monoxide and hydrogen produced from processes such as the gasification of biomass, waste, or coal or reverse water gas shift.

Synthetic methane: Gaseous fuels consisting of combustible hydrocarbons that are manufactured from solid or liquid fossil fuels, electricity, or biomass feedstocks.

Any European policy that incentivizes or regulates gas with a goal of climate mitigation will need to create robust definitions of gas that ensure that only pathways with substantial or full lifecycle GHG reductions compared to business-as-usual natural gas will be supported. The definitions above should assist policymakers in ensuring efforts to reduce GHG emissions are acting as intended.