D5.3 | Guidelines on renewable gas sustainability certification

Deliverable:	**Guidelines on renewable gas sustainability certification**
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Abbreviations

GHG	Greenhouse gas
GO	Guarantee of Origin
LCA	Life Cycle Assessment
MJ	Megajoule
PoS	Proof(s) of Sustainability
PPA	Power Purchase Agreement
PtG	Power-to-Gas
PtX	Power-to-X
RE	Renewable Energy
RED	Renewable Energy Directive 2009/28/EC
RED II	Renewable Energy Directive 2018/2001/EC
RES-E	Renewable energy sources for electricity
RFNBO	Renewable fuels of non-biological origin
RG	Renewable Gas
SDGs	Sustainable Development Goals
SNG	Synthetic Natural Gas

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1 Executive Summary and main conclusion

The RED II includes requirements for biofuels, bioliquids, biomass fuels and other alternative fuels. Also, as one of the first policy instruments, the EU RED II defines criteria for the use of renewable fuels of non-biological origin.

These requirements have to be fulfilled by economic operators and are the precondition that the respective energy carriers can be accounted for the specific targets that are defined within the RED II and the respective national renewable energy targets. For biogenic renewable gases, these requirements include, amongst others, criteria that focus on the sustainable production and supply of the biogenic feedstock, the history of the feedstock production site (i.e., in case agricultural feedstocks are being used) to avoid negative land-use change impacts, as well as criteria for minimum GHG mitigation thresholds compared to defined reference values.

For RFNBOs the RED II sets a GHG mitigation threshold of 70% for all RFNBO compared to the fossil baseline of 94.1 $gCO_2eq./MJ$. A first draft of the delegated act (RED II Art 27) with the specific methodology for the calculation of this draft has been published on the of May 2022 by the European Commission. Furthermore, RED II defines requirements regarding the source of renewable energy that is used for the production of the RFNBOs (so called additionality criteria).

Compliance with the respective requirements and sustainability criteria can be shown by market actors with a sustainability certification process. For this purpose, the EU Commission has recognised a number of certification schemes, which are qualified to show compliance with the RED II requirements. Most of the relevant sustainability criteria included in the RED II have already been introduced for liquid and gaseous biofuels used in the transportation sector in 2009. The RED II is extending the sustainability requirements to industry, heating and cooling. However, most of the experiences from the practical implementation of the RED I criteria, especially for all non-GHG emission-related requirements can be used by the established certification schemes in the process of the RED II implementation. However, due to the differences in the characteristics of the value chains, additional effort is needed to implement the GHG mitigation criteria for gaseous biofuels.

The chapter 6.1.1 summarises exiting materials, tools and approaches to support the actual implementation of the RED II requirements for biobased renewable gases into practice. Due to the potentially high effort for stakeholders, an important element in that regard is the GHG mitigation criteria. Due to the lack of sufficient default values for the relevant biogas and biomethane pathways in the EU, several biogas and biomethane producers might be required to conduct individual GHG calculations. Chapter 3 of this report provides support by discussing an exemplary GHG emission calculation.

The section 6.1.2 discusses potentially relevant aspects related to the practical implementation of the RED II requirements for RFNBOs, including aspects such as for example compliance with the 70% GHG reduction criteria, the additionality of the renewable electricity used for RFNBO production, as well as the aspect of traceability of sustainability information throughout complex supply chains, potentially featuring different traceability models.

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1.1 Main conclusions for biobased renewable gases

For the operationalisation of the RED II requirements for biogas and biomethane, a number of tools and supportive elements have already been developed, e.g., the Biograce calculator or (Moosmann et al. 2021). These elements can be used as a starting point for upcoming certification activities to show compliance with the RED II requirements for renewable gases. However, the process of sustainability certification can be challenging for market actors and further support and effort is needed to reduce unnecessary complications and costs, as well as fundamental differences between the available certification schemes. This does especially refer to the following aspects:

Complexity of the calculations for the GHG reduction requirement

In order to show compliance with the GHG reduction criteria, concerned stakeholders might either use the default values from the Annex of the RED, use individual calculations, based on actual data, or a combination of default values and individual calculations. However, only few default values for biogas and biomethane do exist, which means that individual calculations will be required in most cases. While the general methodology for the calculation can be explained (compare for example chapter 5), especially the process of data collection can be challenging since biogas and biomethane plants often work with a number of farmers and suppliers. Furthermore, the calculation of N_2O emissions from fertiliser application is site specific and complex. Finally, the RED II methodology promotes the use of slurry and manure, as well as increases in soil organic carbon due to improved agricultural practices. Again, the calculation of these credits on an individual level is complex and related to a number of uncertainties in the process of auditing and certification.

Considering these aspects, the introduction of additional default values for the most relevant substrates and feedstocks on a NUTS 2 level in Europe, as well as additional tools (e.g., for the calculation of N_2O emissions) and guidelines (e.g. for the calculation of individual credits for manure/slurry and for improved agricultural practices) seems highly necessary.

Simplifications in the certification process

Depending on their overall capacity, biomethane plants are usually supplied by a significant number of biomass suppliers. This can include farmers, traders or companies operating storage facilities. In case, for example, agricultural biomass is used for the production of biomethane, the collecting of all relevant individual information to calculate the GHG emissions from the cultivation process for each supplier is related to an enormous effort which is time and resource intense. The RED II does in principal allow for a group certification approach for producers of biomass with comparable production conditions. This is a meaningful instrument, which could facilitate the actual implementation of the RED II requirements into practice. However, this approach is not very well explored yet and should be supported by additional guidance from policy makers and the respective certification schemes.

Since certification of the RED II requirements shall ensure a sustainable production of biomass and bioenergy, it is essential to avoid the respective risks for sustainability that are targeted by the RED II criteria. In that regard, it could also be meaningful to discuss, whether specific biogas and biomethane production plants (e.g., those based on wastes ad residues), could be exempted from these requirements and the respective certification effort.

1.2 Main conclusions RFNBOs

As one of the first policy instruments, the EU RED II defines criteria for the use of renewable fuels of non-biological origin. This includes renewable gases, such as Hydrogen or Power-to-Gas. The requirements include a GHG mitigation threshold, as well as criteria related to the source of the renewable energy used for the production of the renewable gas.

Compliance with the RED II GHG mitigation threshold

The experience with bioenergy carriers under the RED/RED II framework shows that the operationalisation of a GHG threshold can be a complex process, which requires guidance and tools, as well as capacity building to support the respective market actors and ensure a transparent and robust certification approach. In that sense, additional guidance documents, which support the implementation of the GHG calculation methodology for renewable gases, is necessary and have to be developed in the near future.

Secondly, the type of carbon source potentially used for renewable gas production is a relevant factor for the GHG assessment, which should be considered appropriately in the respective methodology. Potential carbon sources for RFNBO production are naturally occurring carbon (from direct air capture or geological sources), carbon from fossil origin and carbon from biological origin. This differentiation and the acknowledgement of potential differences related to the climate impact of RFNBOs produced from different carbon sources seems highly relevant. Furthermore, it seems important to address this aspect and provide clear guidance on its consideration in the GHG balance of RFNBOs, since especially for carbon from fossil resources CCU projects and applications might lead to questions about who would be entitled for specific claims on CO_2 credits (Sailer et al. 2021), etc.

In addition, standard values and typical values for the most relevant RFNBOs pathways were already published within the annex of the draft of the delegated Act on RED II Art. 28. However, more are needed for market actors in order to reduce the potential effort that can be associated with a calculation of the GHG mitigation potential of their RFNBO based on actual values.

Additionality of renewable energy for RG production

In practice, the proof of compliance with the additionality concept, which is an important factor for the GHG mitigation potential of the energy carrier and thus, the respective sustainability criterion of the RED, has to be verified by means of a certification process. In the current draft of the delegated act “additionality” is defined by the absence of state aid, as well as a timely difference between the operational date of the power plant and the electrolyser of 36 months.

Depending on the specific definitions and the qualified scenarios for the provision of additional RE, market actors will need to provide specific information, which might come from elements such as metering systems, information from PPAs. This aspect directly refers to the ability to transfer respective information through the supply chain of the energy carriers.

Traceability of information and general information management

One of the key elements of existing sustainability certification for biomass and bioenergy is the traceability of specific information throughout the supply chain or the chain of custody of the certified product. Existing sustainability certification schemes for biomass, biobased materials, and bioenergy use different traceability models to transfer specific information for a certain consignment or batch of a material or product throughout the supply chain and link them to a sustainability claim.

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Depending on the specific definition and the possible approaches to verify the criteria for renewable gases and RFNBOs in the future, connections between different traceability models are necessary. One of the relevant questions is how to organise the transfer of necessary information for a value chain, which might for example combine different traceability models such as book and claim or product segregation in different certification schemes. In any case, it seems likely that the respective system(s) certifying and documenting future sustainability criteria for renewable gases under the RED II will require interfaces and interactions between the elements of the certification schemes involved. However, the transfer of information that might be necessary to prove compliance with the additionality criteria (depending on its final definition and operationalisation) and potential other sustainability criteria for RFNBOs or RE in the future might require additional efforts to combine and expand existing elements for sustainability certification and the registry of RE and renewable gases. This is also necessary in order to avoid risks for fraud or double counting effects of RE. Furthermore, in this context, information regarding the start of operations of RE production plants, as well as information on subsidies received by the producer of RE, can be relevant for downstream market actors. REGATRACE D4.3 recognises the respective challenges associated with the documentation of financial support and developed a draft rule.

Considering the above-mentioned aspects, general awareness from policy makers regarding the possibilities, but also the limitations of certification as a tool to prove compliance with sustainability requirements for renewable gases, is highly important. Thus, it is highly relevant that current and future sustainability requirements for renewable gases are defined in a way which is in general compatible with certification instruments, without creating systems that become too complex or increase the risks for potential fraud an in transparencies. This would also include a harmonisation of the European legislation with regards to the certification and documentation of renewable gases.

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2 REGATRACE in a Nutshell

REGATRACE (REnewable GAs TRAde Centre in Europe) aims to create an efficient trade system based on issuing and trading biomethane/renewable gas certificates/Guarantees of Origin (GO) with exclusion of double sale.

This objective will be achieved through the following founding pillars:

- European biomethane/renewable gases GO system
- Set-up of national GO issuing bodies
- Integration of GO from different renewable gas technologies with electric and hydrogen GO systems
- Integrated assessment and sustainable feedstock mobilisation strategies and technology synergies
- Support for biomethane market uptake
- Transferability of results beyond the project's countries

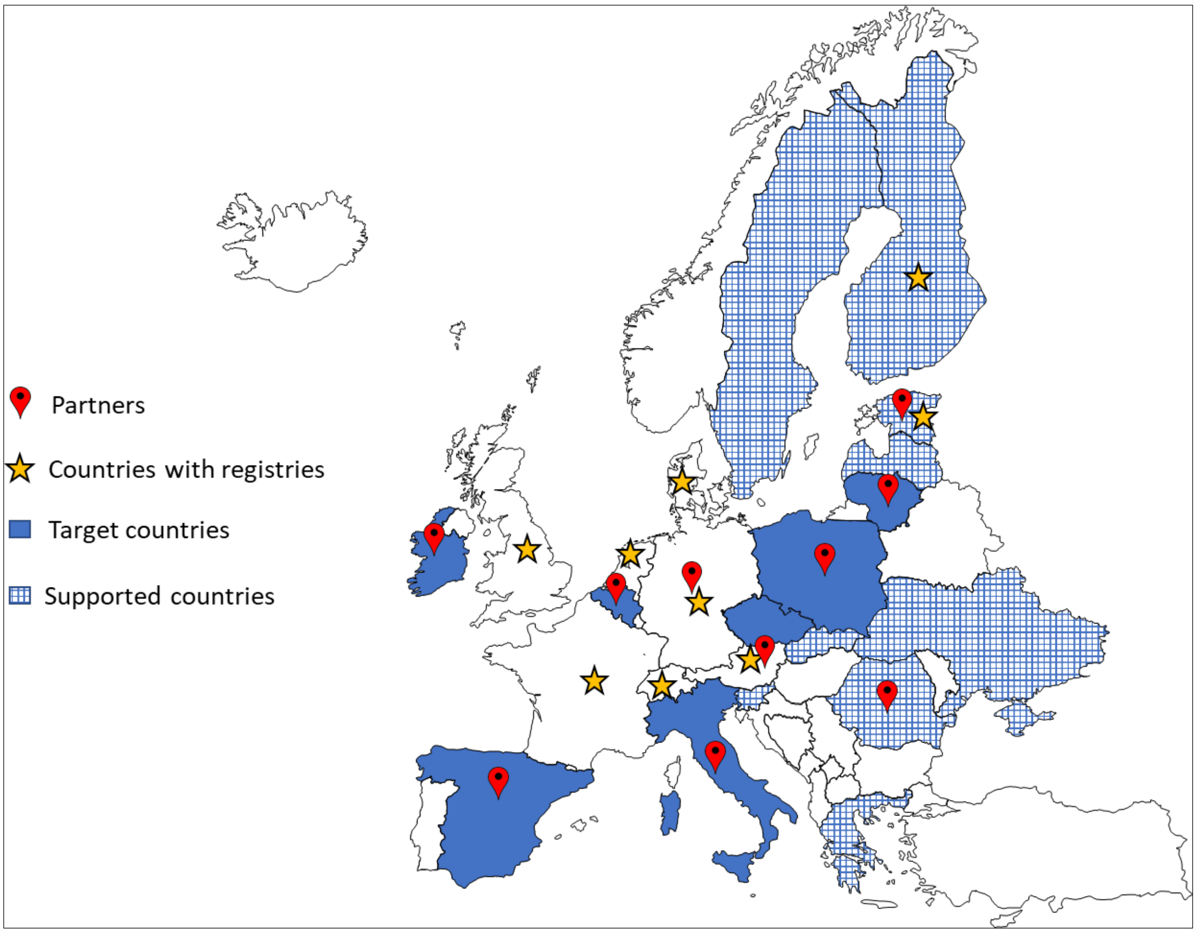

Figure 1: REGATRACE countries and partners

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3 Introduction

Supporting the transformation and conversion of the EU energy system towards the use of a sustainable feedstock and technology base, in line with international targets for the reduction of GHG emissions and reaching the Sustainable Development Goals (SDGs), requires manifold actions from science, policymakers and stakeholders from the industry.

The REGATRACE project is supporting this development by contributing elements fostering trade of renewable gases amongst EU member states and, thus, enabling a more efficient coupling of energy and industry sectors in the EU. However, as recognised by the EU Commission with the introduction of the Renewable Energy Directive, renewable energy technologies are not per se sustainable.

To develop a political framework for the sustainable transformation of the EU Energy system, it is of high importance to understand potential risks and impacts related to the development of renewable gas technologies, as well as to develop associated strategies for risk and impact mitigation. The EU Commission and the Member States have addressed these challenges by developing a policy framework that defines a set of sustainability requirements, aiming to accompany the development of renewable energies and renewable gases in the EU in a sustainable manner. In this context, REGATRACE WP5 addresses specific aspects related to the sustainability of biogas, biomethane, and other renewable gases in order to support stakeholders in the sector with specific information about sustainability characteristics and methodological questions.

3.1 The objectives of WP5 within the REGATRACE project

While REGATRACE in general deals with several topics to support the trade of Renewable Gases in the EU, **REGATRACE WP 5 will address selected aspects related to the sustainability of Renewable Gases.**

These aspects will include:

- **The identification of promising technologies and concepts** for the production of biomethane (both from anaerobic digestion and gasification) and Power-to-Methane (**main focus of D5.1).**
- The **identification of potential hot-spot regions** for the future development of renewable gas capacities in the REGATRACE member states and a description of the respective preconditions (**Main focus of D5.2**).
- O**pen questions and potential barriers for the sustainability assessment and certification** of Renewable Gas concepts are being described and, if possible, potential solutions are being presented (**Main focus of D5.3**).

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3.2 Main objectives of Deliverable 5.3

Over the recent years, an intense debate has been focussed on the development of sustainability criteria, as well as on methodological and administrative infrastructure for the sustainability certification of bioenergy concepts. The very promising and meaningful combination of bioenergy and power-to-methane concepts will generate a number of open questions related to the application of existing rules for sustainability certification to biomethane and power-to-methane combinations. These questions can include, amongst other, aspects regarding the origin of the carbon source used for power-to-methane production, the sustainability of power production, the consideration of by-products, as well as the cross-compatibility between the sustainability frameworks for bioenergy, electricity and possible other sectors to be considered. REGATRACE Task 5.3 was set up in order to identify potentially relevant and open questions related to the sustainability certification of biogas, biomethane and other renewable gases.

Basis for this analysis and discussions are the policy framework that is currently being set by the Renewable Energy Directive II (European Commission 2018) and the related delegated and implementing acts, as well as guidance documents. At the time this deliverable is due, the relevant implementing acts, which are supposed to define specific questions related to the sustainability requirements for non-biogenic renewable gases, are still pending. Thus, this Deliverable collects open questions and challenges for these energy carriers. For biogas and biomethane and other synthetic biogenic renewable gases, most of the open questions related to sustainability certification are on the practical operationalisation of the GHG mitigation requirement of RED II.

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4 Current challenges associated with the sustainability certification of renewable gases

This chapter aims to present a number of topics that seem to be relevant for the further development of a sustainability framework for renewable gases on an EU policy level and the implementation and operationalisation of this framework in practice.

The basis for this description are the sustainability requirements, defined for biogenic and non-biogenic renewable gases in the renewable energy directive. While for the first the criteria are defined in the directive and a certain level of experience from the practical implementation of the sustainability requirements on a national level does exist, further specifications and definitions, as well as guidance regarding the practical implementation of the sustainability requirements for the latter, seems necessary. For this purpose, the EU Commission has announced an implementing act with further definitions and specifications, which was still pending when this deliverable was developed.

4.1 Methodology issues related to the defined criteria and requirements for renewable gases

The RED II includes requirements for biofuels, bioliquids, biomass fuels and other alternative fuels. These requirements have to be fulfilled by economic operators and are the precondition that the respective energy carriers can be accounted for the specific targets that are defined within the RED II and the respective national renewable energy targets. For biogenic renewable gases, these requirements include, amongst others, criteria that focus on the sustainable production and supply of the biogenic feedstock, the history of the feedstock production site (i.e., in case agricultural feedstocks are being used) to avoid negative land-use change impacts, as well as criteria for minimum GHG mitigation thresholds compared to defined reference values.

Compliance with the respective requirements and sustainability criteria can be shown by market actors with a sustainability certification process. For this purpose, the EU Commission has recognised a number of certification schemes, which are qualified to show compliance with the RED II requirements. Most of the relevant sustainability criteria included in the RED II have already been introduced for liquid and gaseous biofuels used in the transportation sector in 2009. The RED II is extending the sustainability requirements to industry, heating and cooling. However, most of the experiences from the practical implementation of the RED I criteria, especially for all non-GHG emission-related requirements, can be used by the established certification schemes in the process of the RED II implementation. However, due to the differences in the characteristics of the value chains, additional effort is needed to implement the GHG mitigation criteria for gaseous biofuels.

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4.1.1 RED II requirements and criteria for bioenergy

RED II includes requirements for bioenergy value chains. While these requirements mostly focus on specific sustainability topics, additionally, a number of efficiency criteria for electricity generation plants with a total rated thermal input greater than 50 MW are being included. Paragraphs 2 to 5 and Article 10 of the aforementioned Directive are particularly relevant for the biogas and biomethane sector.

The fulfilment of the criteria from Article 29 is shown by certificates from recognised certification systems. In order to ensure traceability of the relevant sustainability information, all interfaces in the value chain of electricity, heating and cooling from biogas, as well as biomethane fuel must go through the certification process (Figure 2). In practice, the calculated emissions or information on the use of the default value are passed from one interface to the next (usually on the supply documentation). The GHG saving to show compliance with the GHG mitigation threshold criteria is calculated by the last interface.

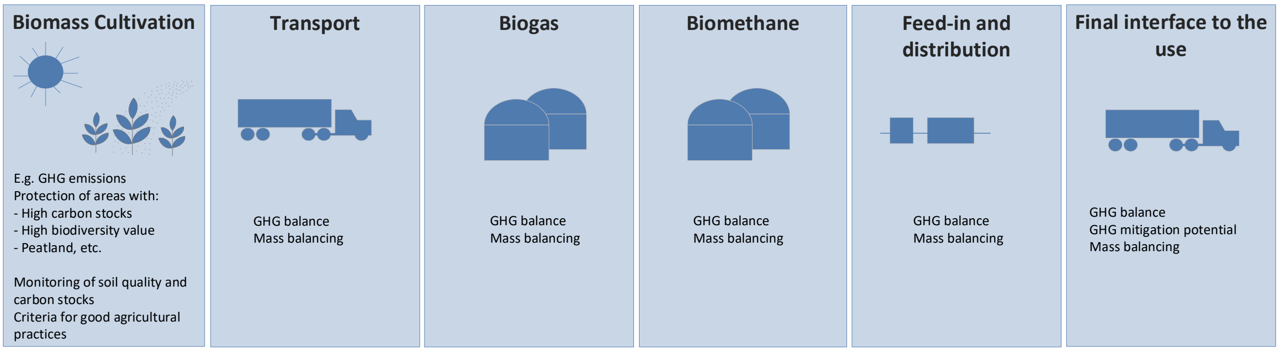

Figure 2 Requirements for market actors in biogas and biomethane value chains according to RED II Article 29 (sustainability, GHG emissions) and Article 30 (mass balancing)

The sustainability criteria in the RED II partly build on the criteria for liquid biofuels, which have been included in earlier versions of the directive. Table 1 presents the respective criteria for bioenergy and describes their novelty (compared to earlier versions of the RED) and a first discussion regarding the relevance or applicability in the different bioenergy sectors.

Table 1 Sustainability criteria according to RED II Article 28 and 29 relevance for supply chains for energy from biogas and biomethane (European Commission 2018)

RED II article	Old/new	Main content	Sector	Relevance
28 (2)	Old	Member States shall require the relevant economic operators to provide information on the transactions carried out and the sustainability characteristics of their biofuels, including their life-cycle greenhouse gas emissions, starting from the place of their production and ending with the fuel supplier placing	Transport fuels/Heat/Cooling/Power	E.g., Operators need access to respective data processing systems or databases (e.g., the NABISY[1]-Database)

[1] NABISY („Nachhaltige-Biomasse-Systeme“) is a web application (database) operated by the German Federal Agency for Agriculture and Food in which proof of sustainability is provided by economic operators.

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		them on the market. Information might be processed in a database system		
29 (2)	New	"Biofuels, bioliquids and biomass fuels produced from wastes and residues originating from agricultural land rather than forestry land shall be taken into account for the purposes of...only if operators or national authorities have established monitoring or management plans to address soil degradation and soil carbon stock. Information on how the degradation is monitored and managed shall be reported in accordance with Article 30(3)."	Transport fuels/ Heat/Cooling/ Power/ Agricultural biomass	Unclear to which extent monitoring plans regarding soil quality and C stock are already taken into account by subsidy requirements (EU direct payments). Risk-based approach
29 (3)	Old	Biofuels, bioliquids and biomass fuels produced from agricultural biomass that are taken into account for the purposes referred to in ... shall not be produced from raw materials obtained from land with high biodiversity value, that is to say, land that had the following status in or after January 2008, irrespective of whether the land still has that status: a) Primary forest, b) Forest with high biodiversity, c) Designated areas, d) Grassland >1ha with high biodiversity	Transport fuels/ Heat/Cooling/ Power/	
29 (4)	Partly new	Biofuels, bioliquids and biomass fuels produced from agricultural biomass taken into account for the purposes referred to in ... shall not be produced from feedstocks obtained from high carbon stock land, that is land that had a status referred to below in January 2008 but no longer has that status: (a) Wetlands (b) continuously forested areas (c) Areas of more than one hectare with trees over five metres high and a canopy cover of 10 to 30	Transport fuels/ Heat/Cooling/ Power/	
29 (5)	Old	Biofuels, bioliquids and biomass fuels produced from agricultural biomass that	Transport fuels/ Heat/Cooling/	

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		are taken into account for the purposes referred to in ... shall not be produced from raw materials obtained from land that was peat bog in January 2008, unless evidence is provided that undrained land does not need to be drained for the cultivation and harvesting of that raw material.	Power/ Agricultural biomass	
29 (6)	New	Criteria for forest biomass at the level of national legislation (a) or at the level of the extraction area (b)	Transport fuels/ Heat/Cooling/ Power/ Agricultural biomass	Not relevant for biogas/biomethane supply chains. Implementing acts with recommendations of the COM on verification will be adopted by 31.01.2021
29 (7)	New	LULUCF requirements for forestry biomass	Transport fuels/ Heat/Cooling/ Power/ Agricultural biomass	Not relevant for biogas/biomethane supply chains. Implementing acts with recommendations of the COM on verification will be adopted by 31.01.2021.

Criteria for GHG emission reductions

Article 29(10) defines the criteria for greenhouse gas reduction and distinguishes between the electricity, heating and cooling sectors on the one hand, and the transport sector on the other (Table 2). In principle, the required emission reduction increases over time and is based on the date for the start of operations of the generation plants. In the transport sector, a GHG reduction of between 50% and 65% is to be achieved. For electricity, heating and cooling, the criteria for GHG reductions are only valid for new plants that started operation on 01.01.2021 or later. These must save 70% greenhouse gases. This minimum saving increases to 80% for plants that will go into operation from 2026 or later.

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Table 2 Criteria for greenhouse gas reductions according to RED II Article 29(10)

Year of start of operations[2]	Necessary GHG reduction	
	Transport	Electricity, heating and cooling
≤ 05.10.2015	≥ 50%	
06.10.2015 – 31.12.2020	≥ 60%	
≥ 01.01.2021	≥ 65%	
01.01.2021 – 31.12.2025		≥ 70%
≥ 01.01.2026		≥ 80%

The GHG reduction is calculated on the basis of reference values for energy from fossil raw materials ("comparators for fossil fuels"). Depending on the application, the values vary between 94 and 212 g CO_2eq/MJ.

Uncertainties regarding national implementation and delegated acts

In general, for the process of transposing these criteria into national law in the EU member states, there is some flexibility and room for interpretation. For example, it is possible to extend the scope for electricity, heating and cooling from biomass fuels, in the sense of lowering the threshold of 2 MW (gaseous biomass fuels) or 10 MW (solid biomass fuels). Also, in theory, additional sustainability criteria can be defined at the national level.

While working on this report, the RED II has not been fully operationalised in all EU member states on EU levels, meaning that the Directive is fully implemented with national legislation. In addition to the national implementation, further specification and guidance on the RED II criteria is also relevant and important. The implementing regulation (European Commission 2021) has to be mentioned in that regard. This document, which was first published as a draft in 2021, specifies several RED II requirements, also in relation to GHG accounting. The regulations described therein will also be included in the final version of certification systems and are to be understood as a supplement to the RED II. As this is an EU implementing regulation, it does not have to be transposed into national law and is relevant for all member states.

4.1.2 RED II requirements and criteria for RFNBOs

As one of the first policy instruments, the EU RED II defines criteria for the use of renewable fuels of non-biological origin (RFNBO). In relation to the general approach for bioenergy, the defined requirements for RFNBO also address the topic of a minimum GHG mitigation potential that should be achieved from the production and use of these fuels. The respective RED II criteria sets a GHG mitigation threshold of 70% for all RFNBO compared to the fossil baseline of 94.1 gCO_2eq./MJ. A first draft of the delegated act (RED II Art 27) with the specific methodology for the calculation of this draft has been published on the 20th of May 2022 by the European Commission. It is open for feedback until 17.06.2022. Due to the timing of the publication of this draft for the delegated act, not all of its content could be considered during the finalisation of this deliverable.

[2] "An installation shall be considered to be in operation when the physical production of biofuels, biogas consumed in the transport sector, and bioliquids, as well as the physical production of heating, cooling and electricity from biomass fuels, has commenced" (Art. 29(10))."

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In addition to the GHG mitigation criterion, the RED II defines requirements regarding the type of renewable energy used for the production. With Article 27 RED II, the draft delegated act defines the criteria for the power sources for the production of RFNBO. These include the following options:

1. direct connection (Article 3), or

2. indirect connection (via the grid)

    2.1. high RES share in the electricity grid of at least 90% (Article 4 (1)),

    2.2. PPA based on (Article 4 (2))

        - additionality

        - temporal correlation

        -geographical correlation, or

    2.3. grid- or system-serving (Article 4 (4)).

Based on a first preliminary interpretation of these criteria, basically, the following options could be considered for the supply of the production of RFNBOs with renewable energy:

- The direct (physical) connection between the RE generation installations and the RFNBO production process.
- Supply of the RE through the grid after having established Power Purchase Agreements (PPAs) with RE generation installations.
- Supply of the RE through the grid, using a system-wide marginal approach

While the exact definition of the criteria and guidance on how compliance with them shall be demonstrated in practice are still pending, the following aspects will briefly focus on a number of open questions which should be considered when developing a robust certification framework for RFNBOs.

4.1.2.1 Compliance with the GHG mitigation threshold for RFNBOs

For showing compliance with the criteria of a minimum of 70% GHG reduction threshold for RFNBOs, the specifics and details of the methodology for the accounting of emissions from the RFNBO production and the respective savings compared to a reference are of high importance. The specific methodology and its implementation have to be developed in the coming months. However, acknowledging the wide range of already existing methodologies and standards, it seems important that the methodology for RFNBOs compatible with the RED II accounting methodology for bioenergy carriers. The same should ideally be envisaged regarding the general accounting logics, system boundaries and general assumptions in already existing and widely established methodologies for carbon footprinting on a product or enterprise level. This is important, especially in order to avoid additional effort and potential inconsistencies for auditors that might be involved in several different certification and verification processes on a company level.

Since the source of electricity and the assessment of its corresponding emission profile will be of high relevance for the overall GHG intensity of the RFNBOs, a general approach to distinguish between elastic and rigid inputs – as stated in the current draft of the delegated act- is meaningful.

Elastic inputs refer to inputs that are additional, meaning that the fuel producer is adding to the renewable deployment or to the financing of renewable energy, or inputs that would e.g. otherwise be curtailed when both the electricity generation and the fuel production plants are located on the same side. According to the current draft of the delegated act, it accounts for a minimum of 50% of the economic output.

So called rigid inputs refer either grid electricity or RE which is diverted from uses in other sectors and its renewable properties have already been claimed there. Furthermore, according to the current draft, they account for a max. of 10% of the economic output.

Depending on the specific rules for the emission factors to be used for rigid and elastic inputs in the overall GHG assessment of RFNBOs, it seems likely that a robust recognition of additional and non-additional inputs will be a crucial element for the operationalisation of the GHG mitigation criteria for RFNBOs. Given that a very strict definition of additional inputs, based for example solely on a physical connection between RFNBO production and a new, off-grid RE installation can become a barrier for the development of RFNBO capacities in the EU, the creation of the "right" regulatory framework for the additional renewable electricity, which is supplied via the grid will be key element to RFNBO capacity developments. That also refers to carbon sources as an input, since additionally produced carbon –even if it is a biogenic carbon source- shall be avoided. Such developments can already be seen in the field.

Second to the type of RE used for RFNBO production, the carbon source is a relevant factor for the GHG assessment, which should be considered appropriately in the respective methodology. Potential carbon sources for RFNBO production are naturally occurring carbon (from direct air capture or geological sources), carbon from fossil origin and carbon from biological origin. This differentiation and the acknowledgement of potential differences related to the climate impact of RFNBOs produced from different carbon sources seems highly relevant. Furthermore, it seems important to address this aspect and provide clear guidance on its consideration in the GHG balance of RFNBOs, since especially for carbon from fossil resources CCU projects and applications might lead to questions about who would be entitled for specific claims on CO_2 credits (Sailer et al. 2021), etc. In addition, standard values and typical values for the most relevant RFNBOs pathways were already published within the annex of the draft of the delegated Act on RED II Art. 28. However, more ones are needed for market actors in order to reduce the potential effort that can be associated with a calculation of the GHG mitigation potential of their RFNBO based on actual values.

Finally, for some renewable gases, direct emissions, e.g., from leakage or incomplete conversion processes, can be relevant contributors to their overall GHG balance and the respective climate impacts of the energy carrier. For example, methane is a relevant greenhouse gas and methane emissions from methane slip or leakage are of high relevance for the development of future renewable gas capacities and infrastructure. Furthermore, in addition to the quantification of direct methane emissions, the selection of the time frame and the climate metrics can have a strong impact on assessment results, since methane has a much higher radiative forcing than CO_2, but is relatively short-lived. Consequently, using climate metrics for Global Warming Potentials over a single 100-year time frame has been critically discussed in a number of publications (Luecke et al. 2022). When discussing aspects related to the GHG assessment of renewable gases or RFNBOs, also effects from direct emissions of hydrogen should be considered. Even though hydrogen is not a direct greenhouse gas, in the atmosphere, it reacts and thus reduces the abundance of the hydroxyl radical, thus leading to a potential expansion of the atmospheric lifetimes of GHGs such as CH_4 (Bond et al. 2011; Weger et al. 2021). Hydrogen is therefore considered an indirect greenhouse gas (Derwent et al. 2006; Derwent et al. 2020; Schultz et al. 2003).

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4.1.2.2 Additionality of renewable energy used for RFNBO production

Following the ambitious targets to increase the share of renewable gases in all energy sectors of the European economy will require a significant amount of renewable electricity. Consequently, it is important to ensure that the electricity demand for hydrogen or other renewable gases will not become a drain on existing renewables in the energy system, which are needed to decarbonise other sectors. Thus, the growing demand needs to be matched with new capacities of renewable electricity (Fritsche et al., 2022).

For this reason, the EU RED framework for the support of renewable energy requires that, to be accounted as renewable, electricity used for the production of renewable energy carriers has to be "additional". (European University Institute. 2021) defines the concept of additionality as "the requirement that renewables-based electricity used in electrolysers for the production of renewable hydrogen is additional to the renewables-based electricity which is used to meet the renewable penetration target with respect to final electricity consumption".

In practice, the proof of compliance with the additionality concept, which is an important factor for the GHG mitigation potential of the energy carrier and thus, the respective sustainability criterion of the RED, has to be verified by means of a certification process. In the current draft of the delegated act "additionality" is defined by the absence of state aid, as well as a timely difference between the operational date of the power plant and the electrolyser of 36 months.

Depending on the specific definitions and the qualified scenarios for the provision of additional RE, market actors will need to provide specific information, which might come from elements such as metering systems, information from PPAs.

4.1.2.3 Traceability of information and general information management

One of the key elements of existing sustainability certification for biomass and bioenergy is the traceability of specific information throughout the supply chain or the chain of custody of the certified product. The Guide to traceability from the UNGC and BSR defines traceability as "*The ability to identify and trace the history, distribution, location and application of products, parts and materials, to ensure the reliability of sustainability claims, in the areas of human rights, labour (including health and safety), the environment and anti-corruption." (UN Global Compact Office 2014).*

Existing sustainability certification schemes for biomass, biobased materials and bioenergy use different traceability models to transfer specific information for a certain consignment or batch of a material or product throughout the supply chain and link them to a sustainability claim. Examples for traceability models are:

- The concept of **product segregation**, i.e., where certified materials and products are physically separated from non-certified materials and products at each stage along the value chain. This shall help to ensure that certified and non-certified materials and products are not mixed and that the end product comes from a certified source (UN Global Compact Office 2014; ISEAL Alliance 2016).
- The concept of **mass balancing**, i.e., a model where certified and non-certified materials can be mixed. In any case, the model has to ensure that the exact volume of certified material entering the value chain must be controlled and an equivalent volume of the certified product leaving the value chain can be sold as certified. This model is used for products and commodities where segregation is very difficult or impossible to achieve. An example of a respective claim that can be made based on this model is: "product contains x per cent of certified components" (UN Global Compact Office 2014; ISEAL Alliance 2016).

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- The **book and claim** model does not necessarily allow for traceability at each stage in the supply chain. This model relies on the link between the volumes of the certified material produced at the beginning of the supply chain and the amount of certified product purchased at the end of the value chain. Thus, a company can obtain sustainability certificates for the volume of certified materials that it puts into the supply chain. Certified and non-certified materials flow freely throughout the supply chain. Sustainability certificates can then, for example, be bought via a trading platform and can be issued by an independent body. Companies that want to make sustainability claims can purchase such certificates (UN Global Compact Office 2014; ISEAL Alliance 2016).

These three, typical traceability models, differ by the extent to which certified and non-certified materials are permitted to mix, as well as by claims that can be attached to the final product.

For the case of biogenic renewable gases under the RED II framework, the basis for the traceability models in recognised certification schemes is an auditing and certification of each of the processes involved in the value chain of the respective product. During auditing and while transferring certified biomass and bio-based products through the supply chain, different certification and auditing documents are being generated. These documents contain relevant information, as well as characteristics of the certified biomass (e.g., feedstock type and origin, low ILUC risk biomass, etc.). In general, different types of documents can be relevant in the generalised, typical supply chain, pictured in the figure below (Figure 3).

Along this supply chain, relevant information is included, amongst others in the following documents:

- The self-declaration: relevant for the interface biomass production, statement to declare general compliance with the relevant criteria for the agricultural/forestry production;
- The audit documentation or report;
- The sustainability certificate (filed for each certified element of the supply chain) and finally the proof of sustainability (including aggregated information, such as for example the overall GHG mitigation potential of a certified biofuel).

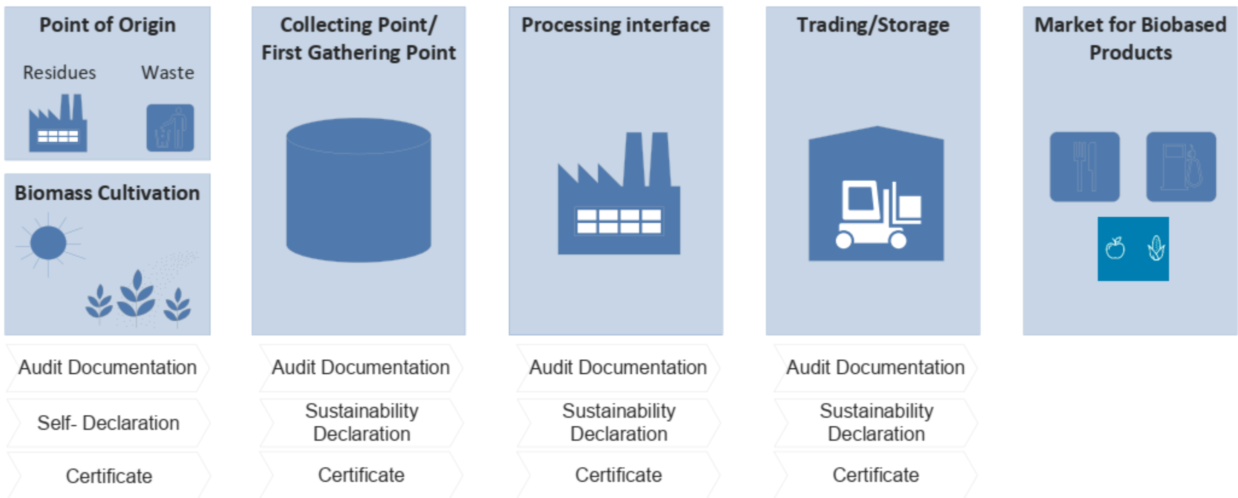

Figure 3 Types of documents and information to be prepared and processed throughout the sustainability certification of a bioenergy value chain under the RED II framework (Star-ProBio Project 2020)

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Typically, this information is partly collected and processed within internal database systems of the respective certification schemes and also national databases and registries such as the NABISY[3] system. When certifying more complex value chains, a transfer of information between market actors, e.g., different certification schemes or even different traceability models, can become relevant.

Depending on the specific definition and the possible approaches to verify the criteria for renewable gases and RFNBOs in the future, connections between different traceability models are necessary. One of the relevant questions is how to organise the transfer of necessary information for a value chain, which might, for example, combine different traceability models, such as book and claim or product segregation in different certification schemes. In any case, it seems likely, that the respective system(s) certifying and documenting future sustainability criteria for renewable gases under the RED II will require interfaces and interactions between the elements of the certification schemes involved. However, the transfer of information that might be necessary to prove compliance with the additionality criteria (depending on its final definition and operationalisation) and potential other sustainability criteria for RFNBOs or RE, in the future might require additional efforts to combine and expand existing elements for sustainability certification and the registry of RE and renewable gases (Figure 4). This is also necessary in order to avoid risks for fraud or double counting effects of RE.

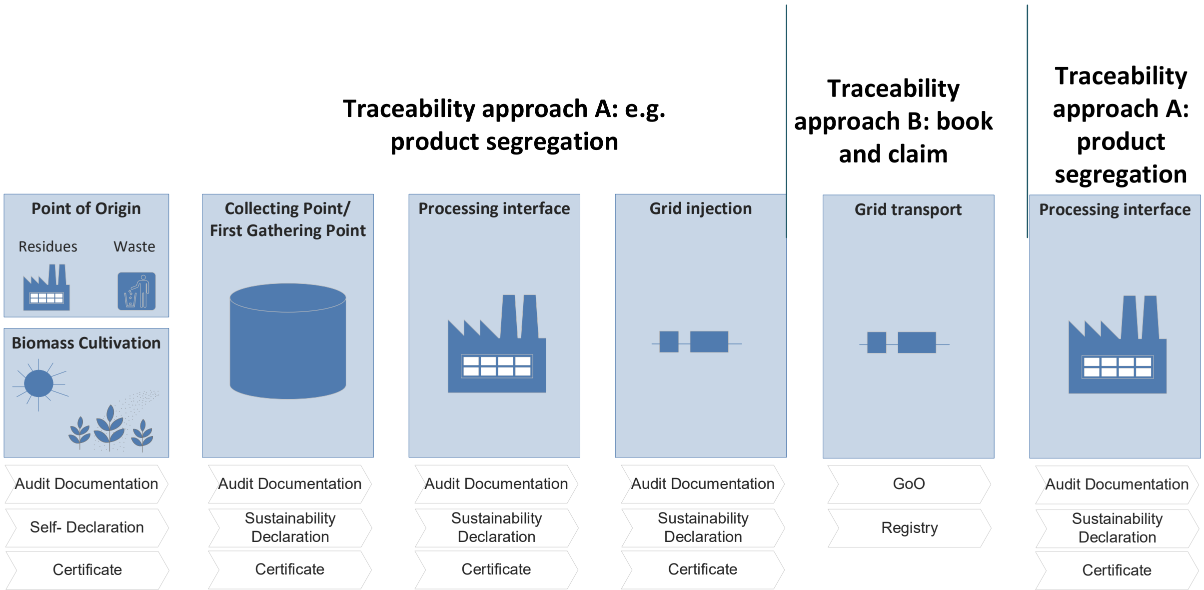

Figure 4 Simplified example for a change in the traceability model and the type of documentation throughout the value chain of an energy carrier

For RE that is, for example, used to produce renewable gases, information that can be relevant for downstream market actor include the start of operations of the RE production plant, information on subsidies received by the producer of RE and potentially already existing certifications. REGATRACE D4.3 recognises the respective challenges associated with the documentation of financial support and developed a draft rule.

Considering the above-mentioned aspects, general awareness from policy makers regarding the possibilities, but also the limitations of certification as a tool to prove compliance with sustainability requirements for renewable gases, is highly important. Thus, it is highly relevant that current and future sustainability requirements for renewable gases are defined in a way, which is in general compatible with certification instruments, without creating systems that become too complex or

[3] https://nabisy.ble.de/app/locale?set=en

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increase the risks for potential fraud an in transparencies. This would also include a harmonisation of the European legislation with regards to the certification and documentation of renewable gases.

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5 Guidance on open questions related to the GHG accounting for renewable biogenic gases in the context of the RED sustainability certification

While the development for practical solutions for most of the open questions, especially for non-biogenic renewable gases, that have been addressed in the previous chapter will require legislation final legislative framework, the open questions related to the sustainability certification of biogas, biomethane, and other biogenic renewable gases are mostly related to the practical implementation of the GHG mitigation criteria. Especially the fact that the RED II includes only few standard values for biogas and biomethane pathways, as well as the annex of the draft delegated act on RED II Art 28 for non-biogenic gases might lead to a situation where producers are required to prove compliance with the GHG threshold based on own calculations. Besides methodological questions and uncertainties, this might impose significant challenges for the collection of the necessary data. One of the reasons for this is that especially larger biogas and biomethane installations are supplied with feedstock by significant number of market actors. This chapter will focus on providing support especially for questions related to methodological aspects of the GHG accounting for biogas and biomethane under the RED II framework. Basis for this are results and findings from a number of projects such as BIOSURF[4], ZertGas[5], Advancefuel[6], Handout[7] and Star-ProBio [8]as well as the work conducted for REGATRACE T5.1, compare (Majer et al. 2021).

5.1 Methodological basis

The methodology for calculating the GHG savings of a biofuel under the RED II builds on the existing regulations for biofuels and bioliquids from RED I. REGATRACE D5.1 (Majer et al. 2021) presents a proposal for a calculation methodology, which operationalises the framework defined in Annex V of the RED II. The basis for GHG calculation methodology defined in REGATRACE D5.1 (Majer et al. 2021) are regulatory requirements derived from the RED II itself, as well as from additional guidance documents from the national implementation, as well as further decisions and notes of the EU Commission. Table 3 provides an overview of the key regulatory documents considered.

[4] Compare http://www.biosurf.eu/wordpress/wp-content/uploads/2015/07/Comprehensive-methodology-on-calculating-entitlement-to-CO2-certificates-by-biomethane-producers.pdf
[5] See: https://www.energetische-biomassenutzung.de/en/projects-partners/details/project/show/Project/ZertGas-607
[6] See: http://www.advancefuel.eu/
[7] See: https://www.dbfz.de/fileadmin/user_upload/Referenzen/Broschueren/Handreichung_Biomethane_englisch.pdf
[8] http://www.star-probio.eu/wp-content/uploads/2017/04/D8.2_SAT-ProBio-blueprint_final-report_3-scalone.pdf

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Table 3 Regulatory aspects with relevance for the GHG accounting of Biogas and Biomethane under the RED II

Title	Source/year	Details
Directive (EU) 2018/2001 of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (RED II) (Europäische Union 2018)	COM/2018	Includes updated sustainability criteria (incl. greenhouse gas savings criteria) for liquid, solid and gaseous biofuels and other alternative fuels and renewable gases. Methodology for calculating GHG savings of bioenergy value chains
Corrections to the Directive (EU) 2018/2001 of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (European Commission 2018)	COM/2018	Listing of some errors in the RED II and presentation of the respective correction
Directive (EU) 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources	COM/2009	Includes sustainability criteria (incl. greenhouse gas savings criteria) for liquid, solid and gaseous biofuels and other alternative fuels and renewable gases. Methodology for calculating GHG savings of bioenergy value chains
Commission decision of 10 June 2010 on guidelines for the calculation of land carbon stocks for the purpose of Annex V to Directive 2009/28/EC (Europäische Kommission 2010; European Commission 2010)	COM/2010	Methodology for calculating the carbon stock and carbon stock changes for actual or reference land use
NOTE on the conducting and verifying actual calculations of GHG emission savings version 2.0 (European Commission)	COM/2017	Guidance and clarification on the calculation and verification of actual GHG saving values
Communication from the Commission on the practical implementation of the EU biofuels and bioliquids sustainability scheme and on counting rules for biofuels (European Commission 2010)	COM/2010	Notes on the implementation of the RED I requirements and the GHG calculation for biofuels

As discussed in the previous paragraphs, compliancy with the RED II criteria for renewable gases will likely be shown by market actors based on sustainability certificates from a recognised scheme. Consequently, we analysed existing methodological principles for GHG accounting in system documents of the certification systems currently recognised by the EU Commission, as shown in Table 4. The schemes differ regarding their specific geographical and sector scopes. Respective documents, relevant for GHG accounting in those schemes with focus on biomethane that could be identified, are included in Table 4.

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Table 4 EU COM recognised voluntary certification schemes for the verification of the sustainability requirements from the EU RED II, focus Biogas and Biomethane

Scheme	EC Recognition	Biomethane Scope	Relevant System document(s)	Details
ISCC	Yes	Yes	ISCC 205: GREENHOUSE GAS EMISSIONS (V3.0)	Inventory of applicable emission factors and standard values
			ISCC 201-3: GUIDANCE FOR THE CERTIFICATION OF BIOGAS AND BIOMETHANE (V3.1)	
REDcert	Yes	Yes	REDcert System document for the GHG accounting (V4.0)	
RSB	Yes	Yes	RSB-STD-11-001 (V.3.2)	
RTRS-EU RED	Yes	No	RTRS EU RED Compliance Requirements for Producers (Version 3.3_ENG) RTRS EU RED Compliance Requirements for the Supply Chain (Version 3.4_ENG)	
2BS Biomass Biofuels Sustainability voluntary scheme	Yes	Yes	2BS-STD-02 (Version 2.0)	
			2BS-PRO-03 (Version 3.6)	GHG calculation presented in detail
Better Biomass (NTA 8080)	Yes	Yes	NTA 8080-1:2015	The relevant document is not publically available
KZR INIG	Yes	Yes	Guidelines for the determination of the life cycle per unit values of GHG emissions for biofuels, bioliquids Description of the INiG System of Sustainability Criteria –general rules	
Austrian Agricultural Certification Scheme	Yes	Partly	Sustainability of biofuels and bioliquids - Information sheet for entrepreneurs/information sheet for registered managers	Only recognised national system. Scope: Austria, limited to feedstock (biomass).

There is a great deal of overlap between the GHG accounting approaches for biofuels and biogas/biomethane. For example, the calculation for the interfaces of biomass cultivation and the transport of the raw materials do not differ, meaning that there is already an established methodology and a long-time experience to be utilised. The special aspects of biogas supply chains, especially biogas production and downstream processing steps (e.g., biogas upgrading) are not exhaustively described in any of the system documents analysed. It is to be expected that new versions with extended GHG calculation methodologies will be published in the course of the renewed recognition of the systems under RED II and throughout the national implementation of the directive in EU Member States.

Additional documents, with partly greater methodological depth or application-related considerations, are presented in Table 5. Parts of the methodology of the RED frameworks, e.g., related to soil carbon content, are based on the methodologies of the IPCC Guidelines for National GHG Inventories. The relevant tools for calculating nitrous oxide emissions from biomass cultivation are also based on the IPCC methodology (Table 5). However, some of these methods are very complex and therefore appear unsuitable for use by economic operators falling under the scope of RED II without further simplifications or adjustments.

Table 5 Project reports, studies and methodological documents relevant to the GHG balancing of biogas and biomethane

Title	Source/year	Details
2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use (IPCC 2006)	IPCC/2006	Methodology for the calculation of nitrous oxide emissions from soil cultivation
2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use (IPCC 2019)	IPCC/2019	Update of the methodology for the calculation of nitrous oxide emissions from soil cultivation
Guide to sustainable biomass production (BLE 2010)	BLE/2010	Guideline for the implementation of the sustainability ordinances (BioStNachV, BioKraftNachV). Illustration of the calculation of the GHG reduction
Technical and methodological basics of GHG balancing of biomethane (Oehmichen et al. 2015)	DBFZ/2015	Guidance on the GHG accounting of biomethane under RED I
Methodology for the calculation and certification of GHG emission caused by the production of biomethane (Majer et al. 2016)	Majer et al./2016	Methodology and calculations of GHG savings of biomethane as a fuel under RED I

To illustrate the calculation approach and support the actual implementation in practise, the methodology defined in D5.1 will be demonstrated with a simplified example calculation. For this, a data basis for a fictious value chain is necessary for this. Table 6 includes the sources and references used for this purpose. The report "Solid and gaseous bioenergy pathways: input values and GHG emissions" by the Joint Research Center is particularly noteworthy (European Commission. Joint Research Centre. 2017). This report presents the methodology and input data for calculating the default values from Annex VI of RED II. Our calculation examples were each based on a plant model from the KTBL Biogas Cost-Effectiveness Calculator. Although the model does not contain any information on GHG emissions, it does provide data and characteristic values (e.g., on energy consumption, gas quantities produced, losses, etc.) that are the basis for the exemplary calculation.

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Table 6 Databases and sources for relevant parameters and emission factors for the GHG calculation of biogas and biomethane

Title	Source/year	Details	reference
Database of LCA results for bio-based commodities	Joint Research Center, 2018		(Giuntoli et al. 2017)
Solid and gaseous bioenergy pathways: input values and GHG emissions	Joint Research Center, 2017	Derivation of RED II default values (maize, manure, biowaste) with input data and sources, calculation based on COM(2016) 767 (RED II proposal)	(Giuntoli et al. 2017)
BioGrace additional standard values v 4d	BioGrace Projekt	Excel table with emission factors, especially for the electricity mix of various countries. Countries and for agro inputs	https://www.biograce.net/
Economic calculator Biogas	KTBL	Web application that allows to generate plant models that can be used as a planning aid	(KTBL 2020)

While reviewing existing standard documents from certification schemes, we also analysed existing GHG calculation tools that might be appropriate for biogas and biomethane producers. Several tools have been developed for use in the context of RED I and are partly freely available. The Biograce tool was recognised by the EU Commission for use in the certification context. Biograce II extends the scope of application in accordance with RED II to include electricity and heat generation from solid and gaseous biomasses. In addition, the RSB and 2BSvs certification schemes provided their own GHG calculators. Among the tools presented in Table 7, only BioGrace II appears to be useful for use in the biogas and biomethane sector. However, other tools can also be useful for calculating GHG emissions from individual upstream and downstream interfaces.

Table 7 Greenhouse gas calculators and tools relevant in the context of biomass, biogas and the Renewable Energy Directive

Title	Methodology	Included pathways	Scope Biogas/ Biomethane	Specialties	Availabiliy	Source/year	Reference
ENZO2	Based on RED II I	Ethanol from sugarcane, sugarbeet, wheat. Vegetable oil (rapeseed, sunflower, soy, palm) Biodiesel	No	excel based	Free	ifeu/2009-2015	https://www.ifeu.de/projekt/enzo2-eine-treibhausgasrechenhilfe-zur-umsetzung-der-biost-biokraft-nachv/
GHGenius		Transport fuels	Yes	excel tool, Focus Canada	Free	(S&T) Squared Consultants Inc.	https://www.ghgenius.ca/
RSB GHG Calculator Tool	Based on RED I RSB GHG Calculation Methodology (RSB-STD-01-003-01	?	?	?	Free for RSB-Members	Roundtable on sustainable biomaterials RSB	https://rsb.org/services-products/ghg-calculator/
UK and Ireland Carbon Calculator				Tool for reporting under the RTFO framework	Free	E4Tech/2018	https://www.gov.uk/government/publications/biofuels-carbon-calculator-rtfo
Biograce I	Based on RED I	Ethanol, FAME, HVO, CNG;	Yes, CNG from Manure, slurry, biowaste,	excel tool based calculator for Land use change Esca N2O	Free	ifeu/2010-2012	https://www.biograce.net/home User Manual Calculation rules

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Biograce II	Based on COM(2010)112 and SWD(2014)259	Electricity, Heating, Cooling from solid and gaseous biomass	Yes	excel tool	Free	ifeu/2012-2015	https://www.biograce.net/biograce2/
GHG calculator (German)	IPCC GWP 100	Feedstock provision, biogas production, CHP	Yes	Web application Focus on biogas production in Bavaria	Free	LfL-Bayerische Landesanstalt für Landwirtschaft Institut für Landtechnik und Tierhaltung	www.thg-rechner.de
GHG calculator (German)	Based on RED II proposal COM(2016) 767 final	Biogas production, CHP combination of feedstocks from agricultural biomass, manure, waste, residues	Yes	excel tool	Free	Fachverband Biogas	https://www.biogas.org/edcom/webfvb.nsf/id/de-treibhausgasrechner
Agricultural GHG calculator V 4.0	Based on RED I	Emissions from biomass cultivation		excel tool	Free	2BSvs/2020	https://www.2bsvs.org/scheme-requirements-and-documents.html
Global Nitrous Oxide Calculator (GNOC)	Based on IPCC Guidelines (Tier 2)	N_2O emissions from biomass cultivation	Yes	Web application	Free	JRC/2013	https://gnoc.jrc.ec.europa.eu/

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5.2 Exemplary calculation for biogas and biomethane

In order to illustrate the rationale of the previously described methodology, this chapter includes exemplary GHG calculations for biomethane production systems. The example shown is based on a guidance document prepared by (Moosmann et al. 2021).

5.2.1 Biogas and biomethane production based on a feedstock mix of manure and grass silage

Our exemplary calculation is based on a Biogas production, using a feedstock mixture of cattle slurry (CS) and grass silage (GS). Data for conversion efficiencies, energy consumption, etc. have been sourced from the KTBL Biogas calculator.[9] Since the plant is operated with a large proportion of cattle slurry, the plant concept includes a treatment of the digestate. The solid phase is separated from the liquid phase by mechanical separation, thus increasing the transportability of the digestate as a fertiliser. The digestate storage systems are covered to minimise storage emissions.

The following sections demonstrate the basic approach for the calculation.

Emissions from raw material extraction and cultivation e_{ec}:

Cattle manure is considered a waste material. As the cattle slurry is produced on the farm premises, no emissions are estimated for extraction ($e_{ec,RG}$=0). For the production of grass silage, the following assumptions are made for the calculation of emissions from the respective agricultural process:

Table 8 relevant parameter for the GHG calculation at the cultivation step

Input parameter	Value	Emission factor	Emissions, $kgCO_2eq/ha*yr$
N-fertiliser	100 kg N/ha*yr	6.14	614
Digestate fertisliser[10]	70 kg Digestate/ha*yr	0.0075	0.53
Diesel	42 l/ha*yr	2.1	88.2
N_2O emissions	3.65 kg N_20/ha*yr	298	1087.7
Total:			**1790.4**

(The value for nitrous oxide emissions from nitrogen and digestate application was calculated with the Biograce-tool).

For this example, we are assuming a grass silage yield of 8 t DM/ha*yr. The raw material is sourced from a permanent grassland with a medium yield level. The area is harvested with four cuts per year. The fertiliser demand is supplied with digestate, serving as an organic fertiliser, with a supplementary mineral fertiliser application. The assumptions on fertiliser requirements are based on (Wendland et al. 2018) The area-related total emissions for the production of grass silage is divided by the area yield. This results in a GHG intensity of **223.8 kg CO_2eq/t grass silage (DM)**. The conversion to FM at a DM content of 35 % results in: **78.3 kg CO_2eq/t grass silage (FM).**

[9] https://daten.ktbl.de/biogas/startseite.do;
[10] The emission factor for digestate refers to transport and application. Nitrous oxide emissions are shown separately for mineral fertiliser as well as for digestate.

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Emissions from transport and distribution of raw materials e_{td}

Since the cattle slurry is produced on the farm, the emissions for the transport of raw materials only have to be calculated for the purchased grass silage. The calculation is based on the following assumptions:

Parameter	Value	Unit
Transport distance, loaded	10	km
Transport distance, unloaded	10	km
Fuel consumption, loaded	0.49	l/km
Fuel consumption, unloaded	0.25	l/km

A truck with a loading capacity of 24 t is used to transport the feedstock to the conversion plant. The emission factor for diesel is 2.1 kg CO_2eq/l. The emissions associated with transporting the grass silage are calculated as follows:

$$e_{td,GS} = \frac{\left(10\ km \times 0.49\,\frac{l}{km} + 10\ km \times 0.25\,\frac{l}{km}\right) \times 2{,}1\ \frac{kgCO_2eq}{l}}{24\ t} = \mathbf{0.65}\ \frac{\boldsymbol{kgCO_2eq}}{\boldsymbol{t\ FM}}$$

Emission savings from improved agricultural management practices e_{sca}

As the plant operator uses cattle slurry, he is entitled to claim a bonus of 45 g CO_2eq/MJ (as indicated in the respective RED II default value). Therefore, the following values are included in the equation:

$e_{sca,CS}$ = 45 g CO_2eq/MJ
$e_{sca,CS}$ = 0 g CO_2eq/MJ

The bonus for the use of manure is given in the unit g CO_2eq/MJ manure (**equivalent to 54 kg CO_2eq/t FM**).

Emissions from processing

Starting with the emissions from processing, the remaining sub-processes are no longer accounted for on a raw material-specific basis, but based on a substrate mix instead. For the calculation of emissions from the biogas process, further key figures are required, some of which can be taken from the output table of the KTBL calculator. The total substrate input of 80,000 tonnes per year includes 60,000 tonnes of cattle slurry and 20,000 tonnes of grass silage.

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Table 9 main technical parameters of the illustrative biogas and biomethane productions

Fermentation and yields	
Feedstocks	**80,000 t/yr**
Feedstock input (DM)	11.2 % of the FM
Feedstock input organic dry matter (oDM)	84.4 % of the FM
Raw biogas production	**3,628,800 m³/yr**
of which biomethane	2,059,344 m³/yr
Energy content	
Raw gas (Hi,n)	20,531,662 kWh / yr
CHP	
Electrical power	450 kW_{el}
Electrical efficieny	**39.8 %**
CHP losses	1.0 %
Thermic capacity	513 kW_{th}
Thermic efficiency	**43.7 %**
Feed in amount of electricity	**3,742,200 kWh_{el}/yr**
Produced amount of heat	4,306,680 kWh_{th}/yr
Biogas upgrading	
Raw gas input	1,949,862 m³⁄a
Methane slip and emissions	1.1% of production
Methane content product gas	98%
Electricity demand	0.23 kWh/m³ raw gas
Product gas production (biomethane)	1,116,709 m³⁄yr
Feed in biomethane	**11,133,589 kWh⁄yr**

Emissions from processing - biogas production e_{p1}

Based on these overall characteristics of the biogas and biomethane production, the data from the following table were used to calculate the emissions from biogas production. The electricity demand was assumed to be 0.1 kWh/m³ raw gas. The process heat is provided by the biogas CHP unit. Emissions from the CHP unit, namely CH_4 and N_2O result. Finally, we assumed direct emissions from biogas leakage in a range of 1% of annual production.

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Table 10 Assumptions biogas production – example

Parameter	Value and unit	Emission factor	Emissions in kg CO_2eq/yr
Electricity consumption	362,880 kWh/yr[11]	0.47 kg CO_2eq/kWh	17,055
Process heat	3.629.459 MJ/a	0.00246 kg CO_2eq/MJ	8,928
Methane leakeage	13,530 kg/a	25 kg CO_2eq/kg	33,8250
Sum			**364,234**

Emissions from Processing – Biogas upgrading e_{p2}

The biogas produced is subsequently upgraded to biomethane. The electricity demand for this step, as indicated in table xx is sourced from the electricity grid. The methane slip is assumed to be 0.1 %. (all assumptions were taken from the KTBL model).

Table 11 main parameters biogas upgrading

Parameter	Value and unit	Emission factor	Emissions, in kg CO_2eq/ a
Electricity demand	448,468 kWh/a	0.47 kg CO_2eq/kWh	210,780
Methane slippage	734 kg/a	25 kg CO_2eq/kg	18,350
Sum			**229,130**

The calculation of emissions for both processing steps per functional unit of biomethane is conducted considering the specific biomethane yield:

$$e_{p2} = \frac{(364{,}234 + 229{,}130)\ \frac{kgCO_2eq}{yr}}{40{,}080{,}919\ \ \frac{MJ\ \ Biomethane}{yr}} \times 1000 = \mathbf{14.8}\ \frac{g\ CO_2eq}{MJBiomethane}$$

Emissions from processing – Grid injection e_{p3}

The biomethane produced undergoes further processing before being fed into the natural gas grid. At the injection station, the gas is compressed to increase the pressure above the pressure of the gas grid and thus enable it to be fed into the grid. This is done with a compressor. Furthermore, the gas is odorised. In this example, it is assumed that due to the high product gas quality from the amine scrubbing, no calorific value adjustment by adding additional gases is necessary. Odourisation is also not included in our calculation. The emissions to be balanced consequently depend on the energy demand of the biomethane compression:

Table 12 Emissions electricity demand compression

Parameter	Value	Emission factor	Emissions, in kg CO_2eq/ a
Electricity demand	0.0025 kWh/m³	0.47 kg CO_2eq/kWh	1312

[11] For the electricity demand of biogas production, we assumed a value of 0.1 kWh/m³ raw gas (FNR Guideline Biogas)

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$$e_{p3} = \frac{1312 \frac{kgCO_2eq}{yr}}{400{,}809{,}919 \frac{MJBiomethane}{yr}} \times 1000 = \mathbf{0.03}\ \frac{g\ CO_2eq}{MJBiomethane}$$

Emissions from transport of biomethane in the gas grid e_{td2}

Emissions from gas losses during transportation in a gas grid have been assumed based on (Vogt 2008). According to this publication, 0.08% of the gas which was fed in to the grid is assumed to be emitted:

Table 13 Emissions biomethane transport

Parameter	Value	Emission factor	Emissions, in kg CO_2eq/ a
(Bio-)methane emissions	587 kg CH_4/a	25 kg CO_2eq/kg CH_4	14,674

$$e_{td2} = \frac{14{,}674 \frac{kgCO_2eq}{yr}}{400{,}809{,}919 \frac{MJBiomethane}{yr}} \times 1000 = \mathbf{0.37}\ \frac{g\ CO_2eq}{MJBiomethane}$$

Calculation of total emissions of biomethane

As a first step, in order to calculate the total GHG emissions, we are converting the emissions from biomass cultivation and transport to the functional unit of 1 MJ biomethane.

For the emissions from cultivation, this is done by multiplying the calculated result per tonne of fresh matter grass silage by the annual amount of grass silage used. The result is divided by the energy content of the biomethane produced.

The similar approach is taken for the calculation of the credit from the use of manure and the emissions from the transport of grass silage to the biogas pant.

Finally, for our example the total emissions for the complete supply chain are calculated as follows:

$$E_{Biomethane} = e_{ec} + e_{sca} + e_{td1} + e_{p1} + e_{p2} + e_{p3} + e_{td2}$$

$$E_{Biomethan} = 39.1 + (-80.8) + 0.32 + 14.8 + 0.03 + 0.37 = \mathbf{-26.2}\ \frac{gCO_2eq}{MJ}$$

Using the comparators for biofuels (94 g CO_2eq/MJ) from the RED II, the emission savings are calculated as follows:

$$GHG\ mitigation\ Biomethane = \frac{94 - (-26.2)}{94} \times 100 = \mathbf{128}\ \%$$

5.2.2 Concluding remarks for the exemplary calculation

For the operationalisation of the RED II requirements for biogas and biomethane, a number of tools and supportive elements have already been developed. Our exemplary has shown how the actual implementation of the RED II GHG calculation approach could look like for biogas and biomethane. However, the process of sustainability certification can be challenging for market actors and further support and effort are needed to reduce unnecessary complications and costs, as well as fundamental differences between the available certification schemes. One important aspect in this regard is the availability of default values. Only a few default values for biogas and biomethane do exist, which means that individual calculations will be required in most cases. Especially the process of data collection can be challenging, since biogas and biomethane plants often work with a number of farmers and suppliers. Furthermore, the calculation of N_2O emissions from fertiliser application is site-specific and complex. Finally, the RED II methodology promotes the use of slurry and manure, as well as increases in soil organic carbon due to improved agricultural practices. Again, the calculation of these credits on an individual level is complex and related to a number of uncertainties in the process of auditing and certification.

Considering these aspects, the introduction of additional default values for the most relevant substrates and feedstocks on a NUTS 2 level in Europe, as well as additional tools (e.g., for the calculation of N_2O emissions) and guidelines (e.g. for the calculation of individual credits for manure/slurry and for improved agricultural practices), seems highly necessary. Scientific projects and industry initiatives can support the development of respective values, background info and tools during the upcoming implementation of the RED framework and the development of a robust certification system for renewable gases.

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