

## Chapter 6

# Assessment of Greenhouse Gas Emission Reduction from Biogas Supply Chains in Germany in Context of a Newly Implemented Sustainability Certification



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**Abstract** Life cycle assessments (LCA) approaches, analysing potential impacts associated with the production and use of biomass for energy and material purposes, have become increasingly important in recent years. An internal project at the Deutsches Biomasseforschungszentrum- DBFZ is investigating, which priority areas have been addressed at the institute with LCA. The preliminary results of the study show mostly practice-linked applications with a focus on the assessment of fuels, their production and technical feasibility. In this publication, we present one of the studies analysed, in which a simplified LCA approach defined in the renewable energy directive (RED II), was applied. Based on primary data from 10 biogas and biomethane supply chains in Germany, the applicability of the RED II greenhouse gas (GHG) emission calculation approach was analysed. Most of the biogas plants assessed were found to be compliant with the required minimum GHG emissions reduction. Storage of digestate, N-fertilization and the use of fossil diesel were identified as the main factors, influencing the GHG intensity of the respective value chains. Additionally, individual calculation requires a high effort for data collection. The availability of tools and default values could therefore support market actors with an efficient implementation of the RED II.

**Keywords** Bioenergy · RED II GHG calculation methodology · Climate impact · Sustainability certification · Biogas supply chains

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## 6.1 Background

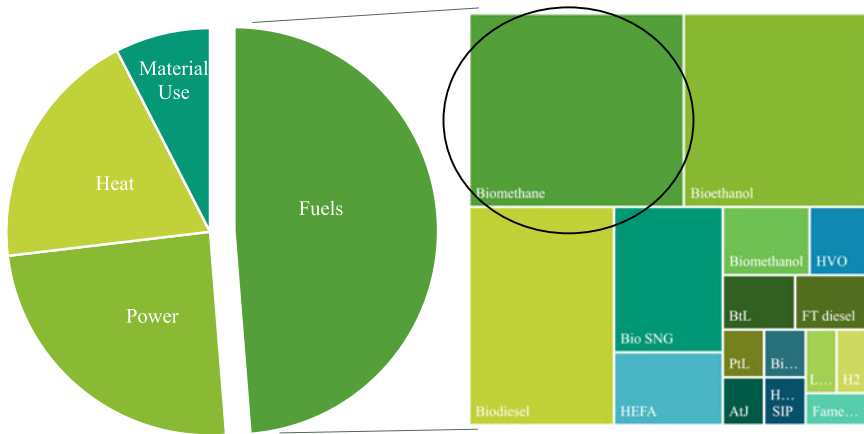
The use of the Life Cycle Assessment (LCA) approach, which can be used to assess potential impacts associated with the life cycles of biomass for energy and material purposes, has become an increasingly important instrument in science and also in political decisions (McManus and Taylor 2015; Sala et al. 2021). Acknowledging the complexity of value chains for biobased products and the variety of research questions from different stakeholder groups, several adaptations of the LCA approach have been developed, allowing assessments on the product, process, company or project level within the framework of the bioeconomy. In order to analyse this development and to prepare the implementation of new approaches and tools for the sustainability assessment of biobased value chains, the Deutsches Biomasseforschungszentrum (DBFZ) has launched an internal project, analysing more than 85 assessment projects, which have been carried out in the DBFZ since 2008.

For this internal project, the inventory data of the various LCA projects were structured and analysed regarding a number of defined criteria (e.g., use and origin of substrates and feedstocks, temporal aspects of the projects, technical background, process focus as well as sector of application, etc.). As an example, Fig. 6.1 shows the distributions of the energy sectors and energy carriers, which have been in the focus of interest in the studies analysed. It can be seen that biofuels for transportation purposes play the most important role, especially biodiesel, bioethanol and biomethane. Biogas and biomethane can be used to supply energy in various sectors. While most biogas plants produce electricity, the upgrading of biogas and the subsequent distribution of biomethane in a gas grid is a promising alternative for operators. Biomethane is considered an interesting bioenergy option, due to its high flexibility and, the potentially high GHG savings, especially from the use of wastes and residues (Bundesanstalt für Landwirtschaft und Ernährung 2021; Wietschel et al. 2019) (Fig. 6.1, right side).

One of the DBFZ focus areas of applied research is on the issues of Renewable Energy Directive (RED) and its implementation/impact on practice. Thus, in this article we present a recently completed project. It is one of the 85 projects evaluated in the internal project and deals with the new certification requirements on the biogas and biomethane market according to RED II.

## 6.2 Introduction

One example of the practical application of the general LCA approach is the GHG emission calculation within the context of the EU RED II. The overall goal of this directive is to promote energy from renewable sources. In the case of energy production from biomass, the directive includes, amongst others, sustainability criteria and criteria for GHG emission savings. Compliance with the criteria is a precondition for public support as well as the consideration of the respective biomass for the fulfilment



**Fig. 6.1** Figure adapted from (Lange et al. 2020). Sectors investigated with LCA in DBFZ projects 2008–2022 (left) and fuels analysed in detail (right); biomethane was at the top of all fuels examined. Explanation of used abbreviations: Bio SNG—synthetic natural gas, HEFA—hydroprocessed esters and fatty acids, HVO—hydrotreated vegetable oils, BtL—biomass to liquid, FT diesel—fischer tropesch diesel, PtL—power to liquid, AtJ—alcohol to jet, HFS-SIP—hydroprocessing of fermented sugars—synthetic iso-paraffinic kerosene, LNG—liquefied natural gas, H<sub>2</sub>—hydrogen, Fame—fatty acid methyl esters/Fage—fatty acid glycerol formal ester

of the national targets for the development of renewable energy, as defined in energy and climate policies. Operators within the scope of the RED II can prove compliance with the sustainability requirements, based on a certificate from a recognized certification scheme. The directive and the respective sustainability requirements have been introduced, firstly for liquid biofuels in 2009. The revised RED (RED II) was published in 2018 and became effective in 2021 (European Commission 2018). This revision included an extension of the scope to electricity, heating and cooling from solid and gaseous biomass fuels used in installations above a fixed capacity threshold, which is 2 MW in the case of gaseous biomass fuels. Annexes of the directive specify GHG emission calculation rules and curtail the goal and scope. The approach can therefore be regarded as a simplified LCA based assessment approach. More comprehensive approaches, in accordance with ISO 14040/14044 for instance, allow for higher degrees of freedom and flexibility regarding certain methodological choices such as for example impact categories, characterization factors, system boundaries, allocation approaches and more. This is why many LCA studies are often consistent in the methodology, but the results are not directly comparable (Roßmann et al. 2019). However, depending on the application, more comprehensive approaches may be favourable for some applications, for example, to investigate extensive research questions. For regulation purposes or within a certification context, more simple and robust approaches seem more manageable and therefore preferable. In case of the RED II approach, additional guidance and supportive elements, such as default

values shall support the operationalisation and feasibility of GHG emission calculations in practice, allowing for a calculation approach which also allows for a direct comparison of the GHG mitigation potential of different biofuel options.

Compliance with the GHG emissions saving criteria of the RED II is shown based on a life cycle approach, meaning that emissions along the entire life cycle of energy from biomass or waste flows are considered. This includes feedstock cultivation or collection, transport, distribution, processing and energy generation. Potential savings are calculated based on comparison to a defined reference value (“fossil fuel comparator” in the terminology of the RED II). In case of electricity from biogas, a GHG emission reduction of at least 70% has to be proven. This applies to installations starting operation as of 2021. This threshold will increase to 80% for installations with a starting date in 2026 or afterwards (European Commission 2021). For defined value chains, respective default values in RED II may be used to reduce the administrative burden for operators in the certification process. This option has been widely applied in the past. Meanwhile, since the market conditions in some energy sectors might allow for price premiums for biofuels with comparably high GHG mitigation potentials, the demand for individual calculations has significantly increased. This is at least the case in Germany, where the system for biofuel blending has originally been based on energy-based targets and was replaced by a GHG mitigation quota in 2015 (Naumann et al. 2021). As a result, there can be market preference for biofuels with higher GHG emissions saving over fuels with less positive GHG emission intensities, dependent on the production costs. For energy production from biogas, which is the focus of this study, default values are available for maize, biowaste and manure only (European Commission 2018). However, substrate mixtures in biogas plants often include a variety of different feedstocks. In addition to the ones mentioned, grass silage, grains and whole-plant silage from different grains, catch crops and sugar beet are further feedstocks, which are currently mainly used in Germany (Daniel-Gromke et al. 2017). For these reasons, the calculation of so-called actual values, in the sense of individual emission calculations, is expected to become more and more relevant.

Different studies have been conducted focussing on the GHG emission calculation for bioenergy concepts in the context of the Renewable Energy Directives. Some of them assessed the methodological approach itself (Börjesson et al. 2015; Czyrnek-Delêtre et al. 2017; Manninen et al. 2013; Whittaker 2015). Others conducted scenario based assessments and focused on specific value chains, feedstocks or regional characteristics, e.g. the production of biomethane from grass (Rasi et al. 2020; Smyth et al. 2009) or biomethane from willow used for heat and transport in Ireland (Long et al. 2021). Rana et al. investigated four different biogas feedstocks in an electricity supply chain in southern Italy based on the legal policy framework in 2015 (Rana et al. 2016). A more recent study from Finland focussed on digestate as co-product from anaerobic fermentation and analysed different methods for co-product allocation (Timonen et al. 2019).

This study adds to this existing inventory, as we analysed the processes concerning requirements on GHG emission mitigation in a certification context, with a specific focus on the perspective of economic operators of bioenergy production. Although the RED II includes the core calculation principles, application in practice can be

difficult because of the abstract and concise way in which they are presented. We therefore developed a biogas- and biomethane-specific GHG emission calculation methodology, aiming at complementing the RED II and designed to support stakeholders within the certification context. Based on this methodology, 10 assessments, for selected existing biogas supply chains, which represent typical cases for German conditions, were examined. Input data for the calculations was obtained from the selected biogas facilities located in different regions across Germany.

Based on the results of the assessments, the following two research questions could be answered:

1. Which are the decisive factors affecting the compliance with the RED II GHG reduction requirements of typical biogas supply chains in Germany?
2. Is the process to proof compliance with the RED II feasible for economic operators in the scope, based on the available regulations, guidelines and tools?

## 6.3 Methodological Approach

### 6.3.1 Method

The assessment of GHG emissions for the 10 biogas plants has been based on the general requirements of the RED II. The principal scope and calculation rules for GHG emission reduction from biogas and biomethane value chains are included in Annex V and VI of the RED II (European Commission 2018) and are compiled in this section. With respect to the system boundaries, there is a slight difference between heat and power from biogas and biomethane for transport. In the former, system boundaries are considered well-to-grid, while the latter can be considered well-to-tank. Following the definitions in the RED II, emissions from fuel in use (combustion in the engine) are set to zero for biofuels. However, non-CO<sub>2</sub> GHG emissions are taken into account for the use of biogas for electricity production. The general rationale behind this approach is the simplified assumption, that the amount of the biogenic CO<sub>2</sub> emitted when biogas is combusted equals the amount of CO<sub>2</sub> absorbed during biomass growth. The three GHGs carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) are to be considered. Conversion factors to calculate CO<sub>2</sub>-equivalents (CO<sub>2</sub>eq) are 1, 25 and 298 respectively. In case of co-digestion of different substrates, which is the predominant biogas process concept in Germany, emissions from the supply chain interfaces up to the feedstock processing are calculated for each feedstock individually (cp. Eq. 6.1). A factor expressing the share of feedstock in the feedstock mix ( $S_n$ ), in terms of the energy content, provides for the contribution of emissions from the single feedstock to the mix. Emissions from feedstock cultivation and extraction ( $e_{ec}$ ), transport and distribution ( $e_{td}$ ), (direct) land use change ( $e_l$ ), processing ( $e_p$ ) and fuel in use emissions ( $e_u$ ) contribute to the total emission value. Negative emissions from carbon capture and storage ( $e_{ccs}$ ), carbon capture and replacement ( $e_{ccr}$ ) as well as from soil carbon accumulation via improved

agricultural practices ( $e_{sca}$ ) can lower the total emission intensity. Moreover, in the latter term, a bonus<sup>1</sup> for emission avoidance via manure digestion can be added.

$$E = \sum_1^n S_n \times (e_{ec,n} + e_{td,feedstock,n} + e_{l,n} - e_{sca,n}) + e_p + e_{td,product} + e_u - e_{ccs} - e_{ccr} \quad (6.1)$$

The calculation of emissions from biomass cultivation ( $e_{ec}$ ) includes nitrous oxides ( $N_2O$ ) emissions from nitrogen (N) application. A draft implementing regulation includes a specification (European Commission 2021). Due to reasons we discuss in this article, we applied a simplified calculation approach described in (Rauh 2010) where needed. This approach is similar to the IPCC Tier 1 approach (IPCC 2006), but limited to direct  $N_2O$  emissions and does not include plant and site specific parameters. Total emissions are to be calculated per 1 MJ biofuel or final energy (functional unit), respectively. This enables the calculation of emissions saving according to formula (6.3) considering the fossil fuel comparators<sup>2</sup> ( $EC_F$ ) given in Annex V and Annex VI of RED II. For combined heat and power processes, total emissions ( $E$ ) need to be allocated to heat ( $EC_h$ ) and electric power ( $EC_{el}$ ) beforehand. This is done by means of exergy allocation according to formula 6.2 (electricity) considering the exergy content of heat ( $C_h$ ) and electricity ( $C_{el}$ ) and the thermal ( $\eta_{th}$ ) and electrical efficiency ( $\eta_{el}$ ).

$$EC_{el} = \frac{E}{\eta_{el}} \left( \frac{C_{el} \times \eta_{el}}{C_{el} \times \eta_{el} + C_h \times \eta_h} \right) \quad (6.2)$$

$$GHG \text{ Emissions Saving} = \frac{EC_F - EC_B}{EC_F} \times 100 \quad (6.3)$$

### 6.3.2 General Approach and Dataset

As part of the overall approach (Fig. 6.2), the first step was the development of a process for the selection of a number of biogas and biomethane plants to be included in the assessment. This was achieved with the help of a questionnaire, which was distributed among biogas plant operators, identifying operators with a general interest for participation. Based on the completed questionnaires, a pre-selection of 37 interested operators was compiled. Building on the information gained

<sup>1</sup> A bonus of 45 g  $CO_2eq/MJ$  manure ( $-54$  kg  $CO_2eq/t$  fresh matter) accommodates for methane emissions during manure storage, which are avoided when manure is used in a biogas digester.

<sup>2</sup> 94 g  $CO_2eq/MJ$  (Biofuels), 183 g  $CO_2eq/MJ$  (electricity), 80 g  $CO_2eq/MJ$  (heat).

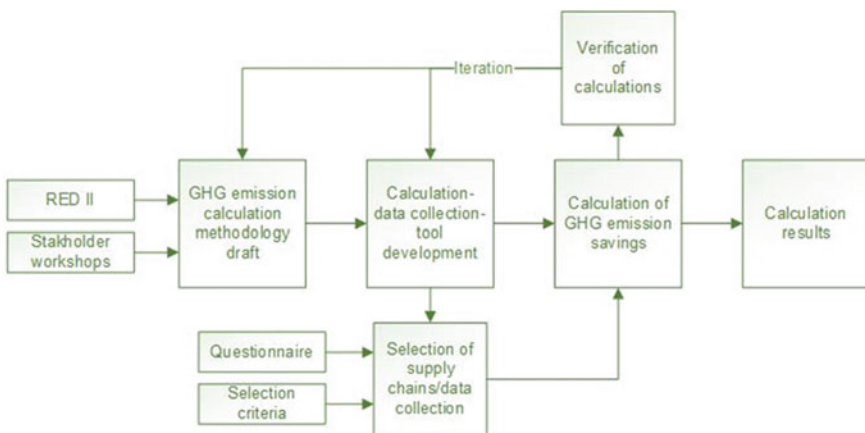
with the questionnaires, the 37 biogas plants were characterized by means of the following parameters:

- Federal state
- Commissioning date
- Type of energy generation: on-site CHP, biomethane CHP, biomethane transport fuel
- Plant capacity (installed capacity, rated capacity, upgrading capacity)
- Feedstocks (waste and residues, cultivated biomass)

The characterisation of the preselected biogas plants enabled a subsequent step, in which we selected 10 facilities covering a wide spectrum of capacities, feedstock and other parameters (Table 6.1). This (final) selection served as sample for the assessment. None of the biogas plants applied a carbon capture technology. Moreover, with respect to the use of cultivated biomass, no direct land use change was reported. In the calculations, the terms  $e_{CCS}$ ,  $e_{ccr}$  and  $e_l$  in formula (6.1) were thus set to zero.

In line with the draft calculation methodology, an excel tool was developed to conduct the calculations and to support the collection of primary data. This tool combined the collected primary data, the relevant comparators for fossil fuels as well as the calculation formulas (6.3 (1)–(3)) and the relevant emission factors. To compensate for gaps in the collected data, some standard calculations values were used in the calculations (Table 6.2).

Calculations were reviewed and verified by a recognized certification body. The verification reports were incorporated into an iterative process for further development of the methodology draft and consequently the supporting tool with the aim to increase its robustness, RED II conformity and practical relevance of the calculations (Fig. 6.2).



**Fig. 6.2** Stepwise overall methodological approach of the ZertGas project to calculate GHG emissions savings in typical biogas and biomethane supply chains

**Table 6.1** Basic process data and feedstock composition of participating biogas plants. Collection of data was done in 2021

Operator ID	Capacity, kW	Digestate storage	Biogas upgrading	Feedstock composition, % <sup>3</sup>		
				Cultivated biomass	Waste and residues	Manure/slurry
1	2,575	Closed	No	83	0	17
8	760	Closed	No	0	62	38
10	305	Closed	No	92	0	8
19	2,864	Open	No	86	0	17
20	360	Open	No	81	0	19
29	330	Closed	No	0	0	100
33	3,077	Closed	Yes	79	4	17
34	3,120	Closed	No	38	2	60
35	2,864	Open	No	59	0	41
36	400	Closed	Yes	100	0	0

**Table 6.2** Various standard calculation values and assumptions used in the calculations

Parameter	Value	Unit	Source
Diffuse CH <sub>4</sub> emissions in biogas fermenter	1	% (of methane yield)	Haenel et al. (2020); IPCC (2019); Vogt (2008)
CH <sub>4</sub> and N <sub>2</sub> O emissions from open digestate storage - manure	69.56	g CO <sub>2</sub> eq/MJ	BioGrace (2021)
CH <sub>4</sub> and N <sub>2</sub> O emissions from open digestate storage - biowaste	21.85	g CO <sub>2</sub> eq/MJ	BioGrace (2021)
CH <sub>4</sub> and N <sub>2</sub> O emissions from open digestate storage - maize	13.51	g CO <sub>2</sub> eq/MJ	BioGrace (2021)
CH <sub>4</sub> and N <sub>2</sub> O emissions from biogas CHP gas engine	8.92	g CO <sub>2</sub> eq/MJ	BioGrace (2021)

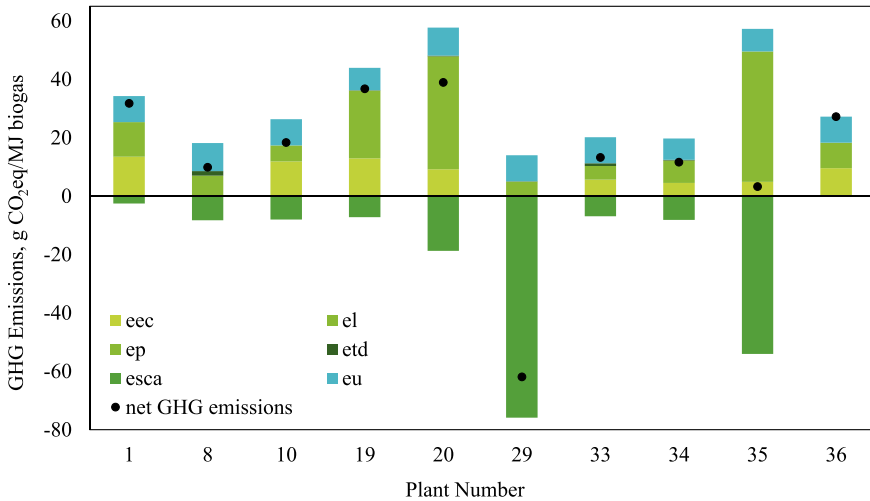
## 6.4 Results

### 6.4.1 Major Drivers and Compliance with RED II

The variety of the selected supply chains (e.g. in terms of plant configuration, feedstock focus etc.) (Table 6.1) is reflected in the calculation results, which reveal significant differences between the analysed plants (Fig. 6.3). Fuel-in use emissions ( $e_u$ ) are

<sup>3</sup> Based on energy content.





**Fig. 6.3** Total GHG emissions per energetic unit of biogas of the assessed supply chains and contributions of the individual terms of formula (6.1) ( $e_{ec}$  = emissions from cultivation and extraction,  $e_l$  = emissions from land use change,  $e_p$  = processing emissions,  $e_{td}$  = emissions from transport and distribution,  $e_u$  = fuel in use emissions,  $e_{sca}$  = emission savings from soil carbon accumulation via improved agricultural management)

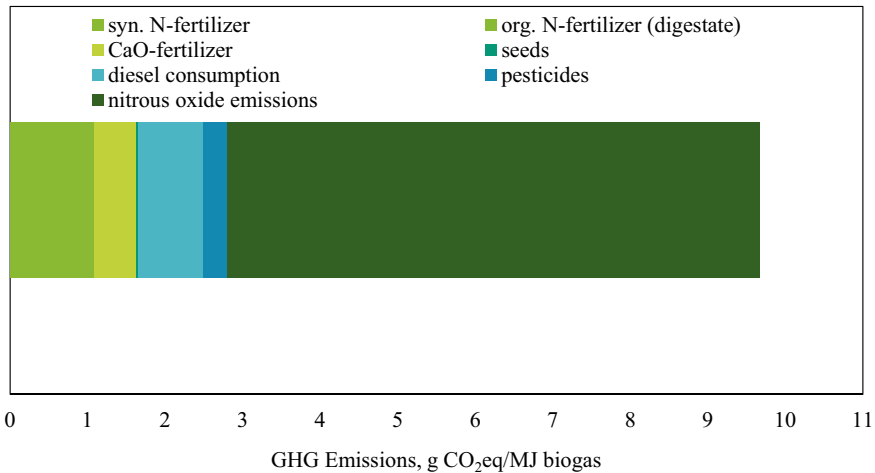
based on standard calculation values (Table 6.2), as in none of the CHPs non-CO<sub>2</sub>-emissions were measured or continuously monitored. For that reason, this contribution does not impact the variety of the total emissions. The feedstock transport ( $e_{td}$ ) did not influence the result largely. The highest contribution was determined for plant no. 8 with 1,6 g CO<sub>2</sub>eq/MJ, which can be explained with a high share of food waste (62%) in the feedstock mix. However, some operators did not report distinguished data for  $e_{td}$ , which is therefore zero in the particular bars in Fig. 6.3. In these cases, emissions from diesel consumption during transport are included in  $e_{ec}$ .

Across all analysed production plants, especially the process of the feedstock processing ( $e_p$ ) showed great differences. The magnitude of emissions accounted for in this term is firstly affected by the type and demand of electrical and thermal process energy (internal or external supply) as well as the methane slip in the digester. For the latter no measurements were conducted at the assessed plants and a standard assumption was used to estimate CH<sub>4</sub> emissions. Secondly and more relevant are emissions from digestate storage, which are considered in  $e_p$ , as well. These showed the highest impact. The processing emissions for biogas plants with open digestate storage (no. 19, 20, 35) are therefore very high when compared with plants with closed digestate storage. The term  $e_{sca}$  includes emission savings from soil carbon accumulation as well as improved manure management practices, namely emission reduction via digestion of manure. All emission savings considered in our assessments are related to the latter. Considering the feedstock composition, the results indicated a correlation between the share of manure in the mix and the CO<sub>2</sub> equivalents saved and

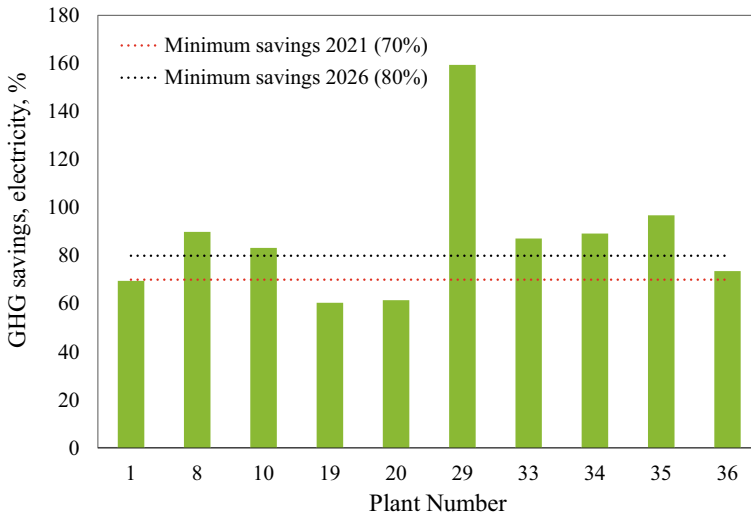
thus decreasing the total emission value. Due to the bonus for manure utilization as feedstock, an entirely manure based feedstock mix enables to even achieve negative emissions, as can be seen from the result of no. 29.

When looking at the results and disregarding emissions from open digestate storage, as these are technically avoidable, the cultivation of biomass remains a relevant driver. This becomes explicitly obvious from the results of plant no. 1, 10, 19, 20, 33 and 36, as their configuration is characterized by higher ratios (around 80–100%) of cultivated biomass in the feedstock mix. Within the cultivation stage there are two major drivers –nitrogen fertilization and the consumption of fossil diesel (Fig. 6.4). The energy intensive production process of synthetic N-fertilizer is one of the reasons for the high contribution of emissions related to N-fertilization. Direct and indirect N<sub>2</sub>O emissions caused by nitrogen application result in high GHG emissions and are the main driver within the cultivation phase. Thereby, according to the appropriate default emission factors (IPCC 2006), nitrogen from synthetic and organic fertilizers both contribute to the release of N<sub>2</sub>O emissions.

The RED II threshold for the GHG emissions saving criteria of electricity from biogas, valid at the time we conducted the study was 70%. Three of 10 assessed plants could not comply with the criterion (Fig. 6.5). The results were in a range between 60 and 160%. Six of the plants could comply with the 80% savings requirement for future installations starting operation from 2026 onwards. The lowest savings were calculated for two plants with open digestate storage systems.



**Fig. 6.4** Total emissions from maize cultivation. Own calculation based on a modeled representative production system



**Fig. 6.5** GHG emission savings of assessed supply chains for electricity from biogas

### 6.4.2 General Feasibility

With respect to the development of a robust and auditable GHG emission calculation by plant operators, we found the applicability of the current GHG calculation approach of the RED II to be low. This was mainly due to the following reasons: The provision of the calculation and data collection tool was not sufficiently supporting the operators to prepare the calculation independently. Further queries, assistance and adjustments were needed to complete a calculation suitable for submission to the auditor.

Equally important, we found the availability of specific input data, emission factors and other, necessary guidance from the EU Commission incomplete. There are many optional specific additives in the biogas process. While primary data on the consumed amount of these products within the balancing period was available, corresponding emission factors could not be included for some additives in the calculation because of inaccessibility. Amongst others, this applied to micro nutrients and more specified products like iron chloride, ferrous oxide and others. Available lists with standard calculation values and emission factors are provided by some certification schemes as part of the system documentation (e.g. ISCC System GmbH 2021) as well as by the European Commission (European Commission 2015, 2021). Very specific emission factors are not included in the mentioned sources and even in more advanced LCA databases some values could not be found.

The methodological framework is determined by the Annexes of RED II and an implementing regulation specifying the former. At the time we conducted the study, the latter was published in a draft version only (European Commission 2021). However, the given information can be assumed likely to become valid, which is

why we considered these regulations. In the named draft implementing regulation, the methodology for calculating nitrous oxide emissions is specified. However, we found the calculation according to this method hardly feasible in practice due to its general complexity. Moreover, additional data (e.g. soil carbon content, soil pH) is needed to calculate a crop- and site-specific emission factor.

## 6.5 Discussion

### 6.5.1 *Assessment of Conformity and Potential for Optimization*

The calculations of GHG emissions saving in typical biogas supply chains showed that GHG emission savings criteria could be met by the majority of assessed cases. Furthermore, the results indicated that even the raised threshold, valid as of 2026 (80%) seems generally achievable. Based on our assessment, we identified the way of digestate storage as the low hanging fruit for optimization of the total GHG emissions saving, because open digestate storage was found to be a major emission source, which is supported by findings of other studies, e.g. (Timonen et al. 2019). Closing an open storage tank is a technically available solution and already widely applied measure that offers a possibility to achieve higher GHG emission savings without conceptual changes of the supply chain. However, the required minimum GHG emissions saving can be achieved with an open digestate storage, as could be shown with the results for plant no. 35. In this plant a relatively high share of manure in the feedstock mix could compensate emissions from digestate storage. Operators willing to further decrease the total emissions should focus on the feedstock mix and increase the share of waste and residue materials in the feedstock mix. Optimization in biomass cultivation could start with questioning the nitrogen application level. Further research should assess if a loss in crop yield due to a reduction of the fertilization level could be compensated by higher GHG emission savings. Emissions from fossil diesel in farming was identified as another relevant driver, as indicated by similar results of other studies, e.g. (Rana et al. 2016). The use of biofuels allows the application of the RED II default values instead an emission factor for fossil diesel (European Commission 2021). In case of biodiesel, these emissions could thus be decreased by 47%-84%, dependent on the biodiesel feedstock (European Commission 2018). An additional option for further improvement of the GHG balance of cultivated biomass could therefore be a substitution of diesel in agricultural machinery by biodiesel or biomethane.

### **6.5.2 Feasibility to Proof Compliance by Operators**

With respect to the feasibility, data collection procedures should be improved, specifically on the level of biomass production and provision. In four of the assessed supply chains, total diesel consumption was considered, but consumption data could not be differentiated between diesel used for farming and for feedstock transport. This might lead to non-conformities in the certification process in two ways. The verification of GHG balances is (in parts) based on a comparison with disaggregated typical values given in Annex V and VI of the RED II on the one hand. This comparison is carried out as a plausibility check. Aggregation of emission values therefore hampers the verification done by auditors and reviewers of certification bodies. On the other hand, calculated emissions have to be reported to the national authority as disaggregated emission values according to the particular terms of formula (6.1). Systematic collection of data by farmers seems therefore required. For cultivated biomass, data on the plot level was not available in all cases. We do not expect significant differences in the results, if data with this level of detail would have been included in the calculations. However, in the actual certification context, data on biomass cultivation is expected to be required on plot level. This will increase the overall complexity and feasibility for operators.

In bioenergy supply chains within the RED II scope, each interface will be certified individually and calculated GHG emissions are transmitted throughout the supply chain from one interface to the next one downstream. Thereby the GHG emission calculation is of limited effort and complexity for a single interface. In energy production from biogas, there are often many interfaces or even all interfaces of one supply chain combined (super interface). That is because biogas plants are often located on farms where parts or all of the biomass of the feedstock mix is produced, processed and converted to energy. As a result, the GHG emission calculation will be done by one operator only. Due to the variety of feedstock streams, this can lead to the challenge of collecting and processing a large amount of data. In our study this specialty occurred by design, as for practical reasons, we approached the operators only and not each interface along the supply chain. However, we argue that this is close to practice and thus our observations with respect to the feasibility within our study are also relevant for the actual certification.

Default values for emissions savings can support the certification process and their application might be preferable, especially for operators not targeting a maximum GHG emission reduction (default values are based on conservative assumptions). While liquid biofuel pathways, especially for first generation biofuels (e.g. rapeseed biodiesel or sugar beet bioethanol) are well represented in the list of default values in the Annexes of the RED II, default values for biogas value chains are very limited to pathways based on maize, biowaste and manure. From the assessed supply chains, total default values would have been applicable in two of 10 cases only due to the variety of feedstocks. This stresses the relevance of the individual GHG emission calculation in the biogas and biomethane sector under current conditions as well as the limitation of default values applicable to biogas and biomethane pathways.

However, a lot of values are needed for individual GHG emission calculation, but standard calculation values such as emission factors, NUTS2 values (regionalized values for  $e_{cc}$ ) and calculation tools supporting the individual calculation are sparsely available. In that respect, we found the needs of the biogas sector to be insufficiently addressed so far. This is mainly linked to the variety of feedstocks included in the supply chains. As the implementing regulation prescribes that the inherent emission factors shall be used (European Commission 2021), this list should include more factors.

The individual calculation of  $N_2O$  emissions according to the implementing regulation was not found practicable due to its complexity. The regulation draft allows using the GNOC (Global Nitrous Oxide Calculator) calculation tool. However, the use of the tool is questionable for different reasons. Firstly, it does not include sufficient feedstocks. Secondly, it was developed for liquid biofuels. In biodiesel production, mostly parts of the plants (grain, rape seeds, etc.) are processed, it is not clear how to rate the use of substrates in the biogas supply chains, where mostly whole plants are processed. The amount of above ground residues left on the field might be different in the two cases. Hence,  $N_2O$ -Emissions would differ as well, as nitrogen in plant residues is one source of such. Consequently, the tool should be updated taking the extension of the RED II scope into account and distinguishing between feedstocks for different bioenergy pathways.

### **6.5.3 *Limitations of the Study***

The individual calculation of GHG emission savings was found challenging for operators. With respect the feasibility, it has to be noted, that the tool we used was not fully optimized for application in practice in terms of usability. Moreover, operators were participating in an assessment of a research project and not in an actual certification process. This might limit our evaluation of the feasibility to some extent.

## **6.6 Outlook**

The results of the wider, internal analysis for 85 projects with an LCA focus, performed at the DBFZ until 2022 will be published in an internal project report. This step is currently under preparation. The publication will also highlight various trends in the field of LCA and bioenergy in Germany over the last 14 years, address relevant developments and discussions such as indirect land use change, social LCA or spatial/regional LCA and their scientific challenges in the coming years.

As a further step to improve internal accessibility, it is planned to transfer selected data sets into a new database format. This database could also be made accessible via a web app and later made available to external users.

Another central point of the internal project is the networking and cooperation with other institutes, scientists and the possible realisation of data collections of common knowledge. Various European projects are working together to make the instrument of LCA more widely and uniformly available across Europe. Strategies are being investigated on how to make data available to the public, whether for comprehensive sustainability assessments, as a guide for policy instruments or for educational transfer. We would like to continue promoting the important exchange of scientific data in the future and are looking for like-minded people for this project.

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