POSSIBILITIES OF REDUCING GREENHOUSE GAS EMISSIONS IN AGRICULTURE ON THE EXAMPLE OF A BIOGAS PLANT

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Abstract

The subject of this publication is to determine the impact of biogas plants on the environment, with particular emphasis on greenhouse gases (GHG) emissions associated with the production and management of biogas as the main plant product. The environmental impact of the agricultural sector as well as the state of development of the biogas market in European Union are presented as background for consideration of greenhouse gas emissions.

One of the economy sectors responsible for GHG emissions is agriculture. One of the solutions of GHG reduction in agriculture is slurry management using biogas technology. It should be emphasized, that biogas not always has favorable emission parameters. The final emission throughout the whole life cycle of this energy carrier depends on many factors. The structure of GHG emissions largely depends on what type of raw material it used for biogas production and in what kind of tanks the digestate sludge is stored. If waste raw materials are used for biogas production, then GHG emission associated with their acquisition is assumed to be zero. On the other hand, if dedicated energy crops are used for biogas production, the emission connected with cultivation of these plants are added to the total GHG emissions. They are directly related to the use of fertilizers and plant protection products, field emissions of nitrous oxide and fuel combustion during the operation of agricultural machinery. Influence on the GHG emission has also the kind id digestate storage tank. If these are closed tanks, there is no emissions to the atmosphere. If tank is open, then methane is emitted directly to the air and is included in the total GHG balance.

Keywords: biogas; biomethane; GHG emission; life cycle; agriculture

1. Introduction

The concentration of greenhouse gases (GHG) in the atmosphere has grown mainly as a result of human activity. Solar radiation reaching the Earth's surface mainly in the form of visible light (radiation with a wave length of (400-700) nm) and to a small extent in the form of shorter ultraviolet and longer infrared waves [28]. A small part (25-30)%

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is reflected, while a significant part of this radiation is passed through the Earth's atmosphere and absorbed by the Earth's surface (land and water), which causes it to heat. The Earth absorbs the energy of visible light, then radiates (reemits) the absorbed energy in the form of an infrared IR beam with lower energy (long-wave radiation with a wavelength of 4 mm to 80 mm), i.e. thermal energy that is largely absorbed by those greenhouse gases in the atmosphere and transferred back to the Earth's surface in the form of reverse radiation and only partially into space [25, 28]. Return radiation heats the Earth's surface again. This phenomenon is known as the "greenhouse effect". The growth of greenhouse gas emissions may be linked to rising temperatures, otherwise referred to as "global warming" [25].

Some greenhouse gases, such as carbon dioxide (CO_2), occur naturally and are emitted to the atmosphere through natural processes like volcanic eruptions or biological activity of flora and fauna. However, CO_2 emissions also result from human activities, primarily the burning of fossil fuels (oil, coal and natural gas). Some other greenhouse gases (for example freons) are generated and emitted solely as a result of human activities (for example, industrial processes) [10].

One of the economy sectors responsible for GHG emissions is agriculture. This sector is responsible for about 10% of total European GHG emissions (Figure 1) [28]. These are mainly methane and nitrous oxide emissions. The source of greenhouse gas emissions in agriculture is primarily the use of fertilizers and plant protection products, as well as improper manure management or enteric fermentation by ruminant animals like cattle.

Given the significant impact of agriculture on greenhouse gas emissions, it is important to look for solutions that will reduce it. One of such solution is slurry management using biogas technology. The environmental benefits of biogas technology are often highlighted in literature, as a sustainable and renewable energy sources, which could be an alternative to fossil fuels [8, 20, 21]. Thanks to the use of biogas as an energy source, it is possible to significantly reduce GHG emissions (especially CO_2 and CH_4), which is particularly important taking into account the progressive global warming and related climate change. Moreover, biogas utilization allows for managing agricultural and zootechnical by products, waste and residue from agri-food industry and municipal wastes [8, 10, 17, 30].

The subject of this publication is to determine the impact of biogas plants on the environment, with particular emphasis on GHG emissions associated with the production and management of biogas as the main plant product. The environmental impact of the agricultural sector as well as the state of development of the biogas market in European Union (EU) are presented as background for consideration of greenhouse gas emissions.

2. Emissions from the EU agricultural sector

As it was mentioned above, agriculture is one of the economy sectors responsible for global GHG emissions (Figure 1). These are mainly methane and nitrous oxide emissions. The main agricultural sources of GHG emissions are [8, 20, 23, 28]:

- enteric fermentation by ruminant animals such as cattle or pig, which are responsible for methane (CH_4) emissions,
- soil nitrification and denitrification, which caused nitrous oxide (N_2O) emissions,
- manure management, which caused methane and nitrous oxide emissions.

In 2015, the agricultural sector produced 42,647.3 kilotonnes of CO_2 equivalent of greenhouse gases (Figure 1) [28]. It is about 10% of the total EU's GHG emissions for that year. Among the EU-28 countries, the largest emitter from the agricultural sector is France (76,367 kilotonnes of CO_{2eq}), Germany (63,884 kilotonnes of CO_{2eq}) and Spain (35,467 kilotonnes of CO_{2eq}). The least emits agriculture of Malta (66,763.67 kilotonnes of CO_{2eq}), Cyprus (559 kilotonnes of CO_{2eq}) and Luxemburg (675 kilotonnes of CO_{2eq}) (Figure 2) [28]. However, direct comparison between the emissions generated by agriculture of individual EU countries is not possible due to the different economic structure and different soil and climate conditions of these countries. Differences in the volume of GHG emissions between countries are determined by types of livestock and their numbers as well as factors such as stock feed differences.

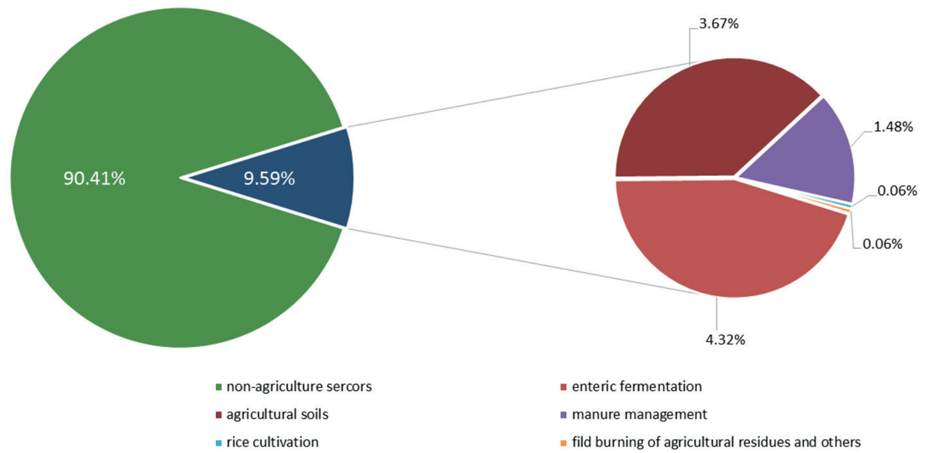

Fig. 1. Total GHG emissions from agriculture and non-agriculture sectors (%) in EU-28 (latest data from 2015) [28]

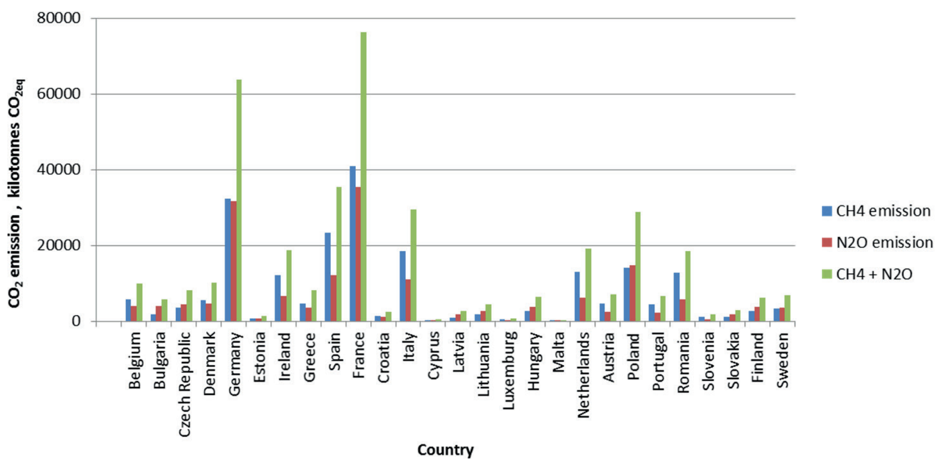

Fig. 2. Emissions from agriculture in EU-28 countries [28]

Emissions from the agricultural sector mainly consist of methane and nitrous oxide emissions, with CH_4 emissions dominating [29]. The largest source of CH_4 emission is enteric fermentation of feed in the stomachs of livestock (mainly cattle) as well as manure management [20].

Emissions of methane from agriculture between 1990 and 2015 (reference period) decreased by 64 304 kilotonnes of CO_2 equivalents across the EU-28 [28]. It is a 21% reduction compared with 1990 levels. Emissions from the two major sources of methane: enteric fermentation and manure management, decreased by 22% and 17% respectively over the same period [28]. The main factor behind the reduction in emissions was the reduced numbers of ruminant livestock, particularly in newer EU Member States. The total cattle numbers in the EU-28 countries fell 26% between 1990 and 2015, and sheep numbers fell 33% [28].

In the EU-28, almost all Member States reduced their emissions of CH_4. The largest percentage decreases during 1990 and 2015 had Bulgaria (-70%) and Slovakia (-64%). Cyprus (+17%), Spain (+7%) and Luxembourg (+2%) were the only countries that have seen an increase in emission during mentioned above period [28]. The larger increases in methane emissions observed in Cyprus and Spain were associated with higher numbers of ruminant animal (cattle and swine).

The largest source of N_2O in the EU-28 are emissions from agricultural soils. Emissions of N_2O from this source decreased in reference period by 17%, mainly due to a general lower use of nitrogen fertilizer on farmland. Emissions of nitrous oxide from agriculture were highest in France and Germany (19% and 17% respectively of the total EU-28 N_2O emission). Between 1990 and 2015 the total nitrous oxide emissions from the agricultural sector in all Member States decreased. Spain is an exception, with an 11% increase in nitrous oxide emissions in agriculture. The biggest reduction of N_2O emission was recorded in Slovakia (-47%), the Czech Republic (-46%), Romania (-45%) and Estonia (-44%) [28].

Changes in agricultural practices in a number of Member States have led to relative differences in the amount of N_2O emitted. However, it is necessary to interpret trends of N_2O emissions in the Member States with care as a number of countries have methodological problems with estimating N_2O emissions from agricultural soils.

Concluding, it is worth noting that GHG emissions (both methane as well as nitrous oxide) from the agricultural sector declined by 20% between 1990 and 2015 [28]. The overall reduction in GHG emissions from agriculture during the reference period can in large part be explained by the reduced use of nitrogenous fertilisers, which led to lower nitrous oxide emissions from agricultural soils, and by a reduction in livestock numbers i.e. cattle and sheep, which led to lower methane enteric fermentation emissions. Reducing the use of fertilizers is associated, among other things, with improving agricultural technology.

3. The biogas market in EU

As it was mentioned in the Introduction, the GHG emission from agriculture sector could be reduced thanks to the use of waste agriculture biomass for biogas production. Biogas is an alternative energy source and has significant potential in GHG emissions reduction [20]. For this reason the dynamic development of biogas sector in the Europe is observed.

By the end of 2017, in the Europe were about 17,783 biogas plants. Within the past five years, 3,122 new plants have been installed to give an increase of 18%. In the year 2017, an increase of 2% in the number of biogas plants was achieved [8].

The International Renewable Energy Agency (IRENA) indicates that Europe has the second largest biogas production potential in the world (35,000 PJ/year). It is only ahead of Asia, whose potential is estimated at 40,000 PJ/year. In the third place are both Americas (28,000 PJ/year). Among EU countries dominates Germany, where almost 11,000 biogas plants operate. Italians are on the second place with a biogas plant number of 1,655 plants. French, Swiss, Czech and United Kingdom have more than 500 biogas plants in Europe. Poland came in eighth with over 300 biogas installations (Figure 3) [8].

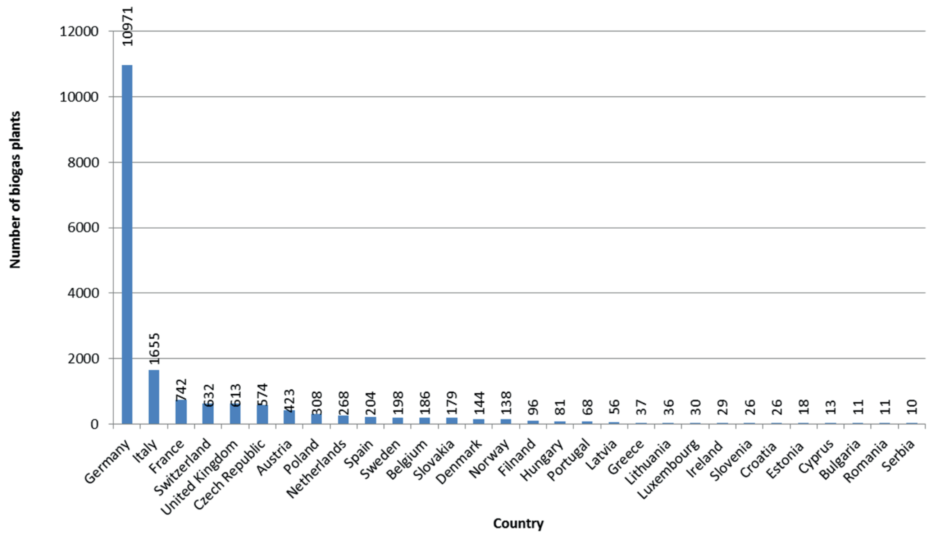

Fig. 3. Number of biogas plants in EU countries [8]

Biogas is obtained mainly from agricultural substrates, which account for over 70% of all raw materials [15]. 16% of gas installations in Europe uses sewage sludge as a substrate, while 8% are installations located at landfills (Figure 4) [8]. In most countries there is one dominant feedstock type for biogas production. In Germany, Belgium, Lithuania, Hungary and Italy, dominates energy crops and agricultural residues which account more than 70% of the feedstocks used. In Denmark, Switzerland and Poland, a big share of industrial organic wastes from the agri-food industry goes toward the production of biogas and electricity from biogas. Sewage at waste water treatment plants is the main feedstock for biogas production in Sweden and the United Kingdom [8, 15].

Agricultural feedstocks comprising livestock manure, farm residues, plant residues and energy crops are the driving force of the European biogas market with a (60-70)% market share [8]. The substrates like organic, municipal waste and organic, industrial waste from the food and beverage industry are still a minority [17, 30]. Sustainable feedstocks should be far more widely used in the biogas sector in order for the biogas market to be part of a sustainable biofuels market.

The new Renewable Energy Directive (RED II) [7], coming into force in 2020, has extended the sustainability criteria from the transport sector to all energy sectors, also addressing biogas and biomethane used in the heat, power and transport sectors. RED II requires producers to calculate of their GHG emissions reduction, which must reach (50-80)%

savings[3], relative to the Fossil Fuel Comparator (FFC) [7]. In order to reach these thresholds, producers have to focus on the sustainable feedstock types outlined in the Annexes of RED II directive. Annex IX, part A lists the feedstocks for advanced biofuels and biogas. Materials listed in the part A include, among others raw materials such as biomass fraction of mixed municipal waste, biomass fraction of industrial waste not fit for use in the food or feed chain, animal manure and sewage sludge or crude glycerin [3. 17, 30]. From the raw materials listed in Annex IX, it is clear how important waste raw materials will have for the biofuels and bioenergy market [7]. One of the most important advantages of waste as a raw material for biofuel and bioenergy production is that they shall be considered to have zero life-cycle greenhouse gas emissions up to the process of collection of those materials irrespectively of whether they are processed to interim products before being transformed into the final product [7].

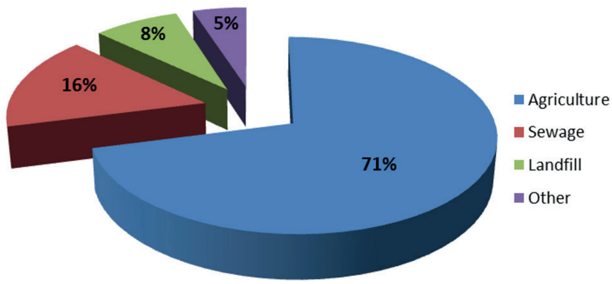

Fig. 4. Percentage share of feedstock use by type according to number of biogas plants [8]

4. GHG emission from biogas plant

4.1. Methods of GHG emission calculation

In the literature for the investigation of GHG emissions in whole lifecycle of products or services various methodological approaches are used. All existing approaches are often part of a life cycle assessment (LCA) methodology, which is standardized and generally defined in ISO 14040 and 14044 standards. Life Cycle Assessment (LCA) is a technique designed to assess the environmental risks associated with the product system or activity either directly by identifying and quantifying the energy and materials used and the waste introduced into the environment or indirectly by evaluating the environmental impact of such materials, energy and waste [8, 30]. The assessment relates to the whole lifespan of the

3 At least 50% for biofuels, biogas consumed in the transport sector, and bioliquids produced in installations in operation on or before 5 October 2015, at least 60% for biofuels, biogas consumed in the transport sector, and bioliquids produced in installations starting, operation from 6 October 2015 until 31 December 2020, at least 65% for biofuels, biogas consumed in the transport sector, and bioliquids produced in installations starting operation from 1 January 2021 and at least 70% for electricity, heating and cooling production from biomass fuels used in installations starting operation from 1 January 2021 until 31 December 2025, and 80% for installations starting operation from 1 January 2026.

product or activity, from the mining and mineral material processing, product manufacturing process, distribution, use, re-use, maintenance, recycling up to the final disposal and transportation. LCA directs the study of environmental impact of the product system to the area of ecosystems, human health and the resources used [9, 11, 14, 17, 22, 20].

The LCA approach described within these standards is general and contains various levels of freedom regarding aspects such as system boundaries, impact categories and characterization factors. Considering the above, in Annex V of the EU RED directive are given the methodology for the calculation of GHG emission in whole biofuels and bioenergy life cycle [6]. Proceeding with calculations in accordance with the guidelines given in the directive allows to avoid methodological errors.

To limit the above mentioned various degrees of freedom regarding the methodological setting, the EU RED methodology defines the basic framework of the investigation by a clear definition of:

- the system boundaries (well-to-wheel),
- the allocation of by-products (based on the heating value of products and by-products),
- the functional unit for the expression of the result calculated (g CO_{2eq}/MJ),
- the life cycle impact assessment category (GHG emissions),
- the characterization factors for the conversion of greenhouse gases into CO_{2eq} (CO_2 – 1, N_2O – 296, CH_4 – 23),
- the Fossil Fuel Comparator (Tab. 1),
- interpretation of the result.

Tab. 1. The Fossil Fuel Comparator from the current and new RED directive

RED directive [6]	RED II directive[4] [7]
For biofuels, the fossil fuel comparator EF shall be 83,8 g CO_{2eq}/MJ.	For biomass fuels used as transport fuels, the fossil fuel comparator EF(t) shall be 94 g CO_{2eq}/MJ.
For bioliquids used for electricity production, the fossil fuel comparator EF shall be 91 g CO_{2eq}/MJ.	For biomass fuels used for the production of electricity, the fossil fuel comparator ECF(el) shall be 183 g CO_{2eq}/MJ electricity or 212 g CO_{2eq}/MJ electricity for the outermost regions.
For bioliquids used for heat production, the fossil fuel comparator EF shall be 77 g CO_{2eq}/MJ.	For biomass fuels used for the production of useful heat, as well as for the production of heating and/or cooling, the fossil fuel comparator ECF(h) shall be 80 g CO_{2eq}/MJ heat.
For bioliquids used for cogeneration, the fossil fuel comparator EF shall be 85 g CO_{2eq}/MJ.	For biomass fuels used for the production of useful heat, in which a direct physical substitution of coal can be demonstrated, the fossil fuel comparator ECF(h) shall be 124 g CO_{2eq}/MJ heat.

[4] The RED II Directive will be at force since June 2020.

Greenhouse gas emissions from the production and use of transport fuels, biofuels and bioliquids shall be calculated as [6]:

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr} - e_{ee} \quad (1)$$

where

E = total emissions from the use of the fuel, [g CO_{2eq}/MJ];

e_{ec} = emissions from the extraction or cultivation of raw materials [g CO_{2eq}/MJ];

e_l = annualised emissions from carbon stock changes caused by land-use change [g CO_{2eq}/MJ];

e_p = emissions from processing [g CO_{2eq}/MJ];

e_{td} = emissions from transport and distribution [g CO_{2eq}/MJ];

e_u = emissions from the fuel in use [g CO_{2eq}/MJ];

e_{sca} = emission saving from soil carbon accumulation via improved agricultural management [g CO_{2eq}/MJ];

e_{ccs} = emission saving from carbon capture and geological storage [g CO_{2eq}/MJ];

e_{ccr} = emission saving from carbon capture and replacement [g CO_{2eq}/MJ];

e_{ee} = emission saving from excess electricity from cogeneration [g CO_{2eq}/MJ].

Emissions from the manufacture of machinery and equipment are not taken into account. The emissions from fuel use (e_u) are assumed to be 0 for biofuels and bioliquids.

The GHG emissions from raw material production (e_{ec}) include the GHG emissions from cultivating and harvesting raw materials as well as the GHG emissions from the production of chemicals and other inputs used for cultivation. In case of use wastes or residues as a feedstock, the emission of their collection must be included into calculation.

Land use change taking place after the cut-off date of 1 January 2008 has to be included in the calculation of the GHG emissions. Land-use change should be understood as referring to changes in terms of land cover between the six land categories used by the IPCC (forest land, grassland, cropland, wetlands, settlements and other land) plus a seventh category of perennial crops, i.e. multi-annual crops whose stem is usually not annually harvested such as short rotation coppice and oil palm (because such land has features of both cropland and forest land).

According to the communication from the Commission on the practical implementation of the EU biofuels and bioliquids sustainability scheme as well as on counting rules for biofuels (2010/C 160/02), improved agricultural management (e_{sca}) like shifting to reduced or zero-tillage, improved crop rotations and/or cover crops, including crop residue management, improved fertiliser or manure management or use of soil improver (e.g. compost) can be included into total GHG emission [6]. Emissions savings from such improvements can be taken into account if evidence is provided that the soil organic carbon levels have increased, or solid and verifiable evidence is provided that it can reasonably be expected to have increased, over the period in which the raw materials concerned were cultivated.

As part of the biomass production and supply, emissions from carbon stock changes (e_l) need to be considered in case land not yet used for agricultural production has been converted for biomass production after January 2008. The Commission has published an appropriate guideline. Contrarily, a bonus of 29 g CO_{2eq}/MJ biofuel (as part of the term e_l) can be attributed in case the biomass is produced on degraded or contaminated land (with this status in, or after January 2008) and the biomass cultivation initialized by the biofuel production helps to valorize land which would not be used otherwise [6]. This bonus is added in the overall calculation (and subtracted from emissions from cultivation, which also need to be considered for scenarios of biomass production on degraded or contaminated land).

Every processing facility must ensure that all GHG emissions from processing (e_p) are incorporated into the calculation of the GHG emissions. This includes emissions from processing itself, from waste and leakage and from the production of chemicals or products used in processing [6].

The last element of individual calculations are emissions from transport and distribution (e_{td}). This includes the transport and storage of raw and semi-finished materials and the storage and distribution of the final product [6].

Apart from the emission mentioned above, potential emission savings from carbon capture and geological storage (e_{ccs}) as well as from carbon capture and replacement (e_{ccr}) can be considered in the calculations. Especially e_{ccr} can be an interesting option for biomethane producers to utilise carbon dioxide as a by-product of the fermentation and upgrading process [6].

The last stage of the calculation is to determine the reduction of emissions throughout the supply chain in relation to the FFC (see Table 1) [6, 7].

4.2. Results of GHG emission calculation for biogas plant

Biogas is produced by anaerobic digestion. For digestion process a wide spectrum of organic feedstocks are used. In the Europe, three main feedstocks were mostly use for anaerobic digestion. We include such raw materials as an energy crop (e.g. maize silage), agricultural waste (e.g. manure) and municipal and agro-industrial biowaste [3, 14, 17, 30]. On the choice of raw material for the methane fermentation process depends largely the final GHG emission. In the case of intentional crops, such as the cultivation of maize for silage, it is necessary to incur appropriate material and energy expenditure. The cultivation of maize for silage is connected with the necessity of land use for the cultivation and the use of mineral fertilization and plant protection products, whose production and use on plantations are energy-consuming and cause significant emissions of dust and gaseous pollutants into the air. The GHG result is also significantly affected by the combustion of diesel fuel during field work and transport [18]. If, on the other hand, raw materials used for the methane fermentation process have the status of waste or residue, then, according to the RED directive, zero GHG emission value is assumed for the stage of their acquisition (see Table 2). The use of this type of raw materials allows for a significant reduction in GHG emissions already at the raw material stage. This difference is up to several dozen percent compared to, e.g., maize silage, the acquisition of which is associated with significant GHG emissions (Table 2).

The next stage, which is included in the calculation of GHG emissions, is the methane fermentation process. The main product of this process is biogas, which can be used for electricity and / or heat generation (in CHP) or, after an additional upgrading process, injected into the natural gas grid as biomethane [5, 11]. Combustion of biogas or biomethane in an internal combustion engine is primarily characterized by a reduction in carbon monoxide emissions, a significant reduction in hydrocarbons emissions and nitrogen oxide emissions, and a significant practical elimination of particulate emissions compared to the burning of conventional energy carriers [1, 18, 24].

The digestate storage method is also very important, as it has a significant impact on methane emissions [10,13 23]. The digestate can be stored in open tank storage or closed tank storage. Closing the digestate storage tanks avoids uncontrolled methane emissions, and thus contributes to a significant reduction in GHG emissions throughout the entire life cycle (see Table 2 and Figure 5) [3].

The Renewable Energy Directive specifies the minimum GHG emissions saving that biofuels and bioenergy must comply with in order to count towards the renewables targets and to be eligible for public support. Annex V (liquid biofuels) and Annex VI (solid and gaseous biomass) of the RED provide a list of default greenhouse gasses emission values [6].

Table 2 provides estimated default values of greenhouse gas emissions and the emission reductions for the whole life cycle of electricity generation from biogas [10]. According to the table, biogas produced from liquid manure has the greatest potential for GHG emissions reduction throughout the whole life cycle. This result is not only caused by zero greenhouse gas emissions at the stage of obtaining the raw material, but also by the high premium granted for improving the slurry management system (including reduction of methane emissions associated with slurry management) [10, 11]. In addition, digestate storage is also important. If closed tanks are used, additional methane emissions are avoided [10,13 23].

The least favorable results are attributed to biogas obtained from methane fermentation of maize silage, which is directly related to the process of growing maize for silage [10, 11, 22].

The structure of greenhouse gas emissions results from the expenditure used for the production of agricultural raw materials. It is dominated by emissions related to nitrogen, phosphorus and potassium fertilization (NPK fertilization) and field emissions of nitrous oxide associated with the distribution of nitrogen fertilizers on the soil surface. If the dose of nitrogen fertilization used is higher, then the overall greenhouse gas emissions from the cultivation of agricultural raw materials is greater. The GHG emissions associated with diesel consumption are closely related to the number of field operations. In the case of annual plants, the need to perform every year soil preparation and sowing operations as well as plantation care (plant protection and fertilization) translates into significantly higher fuel consumption and associated greenhouse gas emissions. Biomass transport to a biogas plant has a very small share in the overall structure of greenhouse gas emissions [10, 23].

Tab. 2. Default values of emission characteristics and relative limits of greenhouse gas emissions for electricity generation from biogas throughout the life cycle [10]

Production system		Technology	Default values [g CO_{2eq}/MJ]						Reduction of GHG emissions relative to the fossil equivalent [%]
			Cultivation	Biogas production	Combustion in the engine	Transport	Bonus	Sum	
Wet manure	Case I*	Open digestate	0	97.4	12.5	0.,8	-107.3	3	94
		Close digestate	0	0	12.5	0.7	-97.6	-84	237
	Case II**	Open digestate	0	106.2	12.,5	0.8	-107.3	12	82
		Close digestate	0	8.2	12.5	0.7	-97.6	-76	214
	Case III***	Open digestate	0	119.,1	12.5	0.9	-120.7	12	82
		Close digestate	0	8.9	12.5	0.8	-108.5	-86	229
Maize silage	Case I	Open digestate	15.8	18.9	12.5	0	–	47	22
		Close digestate	15.5	0	12.5	0	–	28	54
	Case II	Open digestate	15.8	29.1	12.5	0	–	57	14
		Close digestate	15.5	10.1	12.5	0	–	38	43
	Case III	Open digestate	17.8	32.5	12.5	0	–	63	6
		Close digestate	17.4	11	12.5	0	–	41	39
Biowaste organiczne	Case I	Open digestate	0	30.6	12.5	0.5	–	44	27
		Close digestate	0	0	12.5	0.5	–	13	78
	Case II	Open digestate	0	42.3	12.5	0.5	–	55	18
		Close digestate	0	11.5	12.5	0.5	–	24	64
	Case III	Open digestate	0	47.3	12.5	0.5	–	60	10
		Close digestate	0	12.6	12.5	0.5	–	26	62

* Refers to production paths in which electricity and heat for the process are produced in a CHP plant.

** Refers to production paths in which electricity for the process is taken from the national grid and heat comes from the CHP engine.

*** Applies to production paths in which electricity for the process is taken from the national network, and heat comes from the combustion of biogas in the boiler.

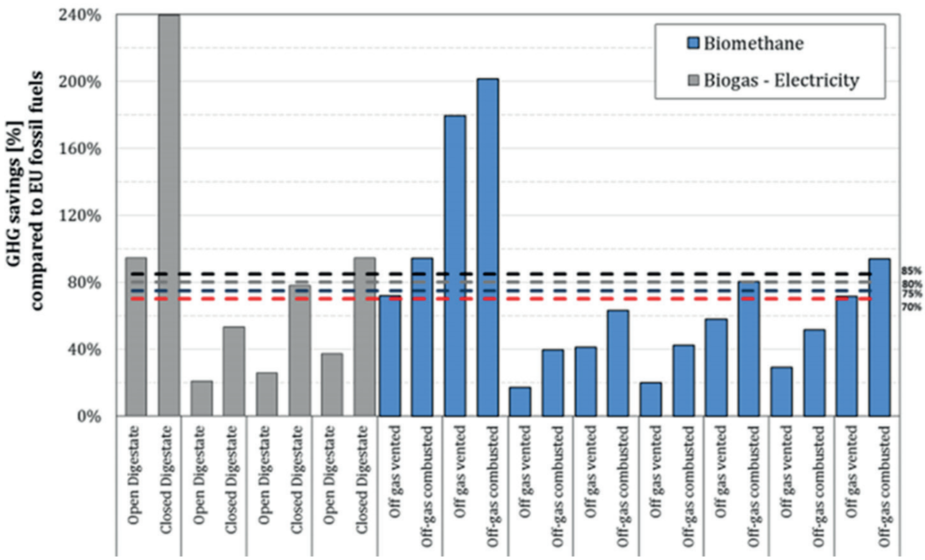

Fig. 5. Reduction of GHG emissions for the most representative biogas and biomethane pathways [10]

5. Conclusions

One of the economy sectors responsible for GHG emissions is agriculture. This sector is responsible for about 10% of total European GHG emissions. These are mainly methane and nitrous oxide emissions caused enteric fermentation by ruminant animals, soil nitrification and denitrification, use of fertilizers and plant protection products and manure management. Given the significant impact of agriculture on greenhouse gas emissions, it is important to look for solutions that will reduce it. One of such solution is slurry management using biogas technology. The environmental benefits of biogas technology are often highlighted in literature, as a sustainable and renewable energy sources, which could be an alternative to fossil fuels [1, 2, 4, 5, 12, 16, 21]. The dynamic development of the biogas market has been observed in Europe in recent years. In 2012-2017, the number of biogas plants in Europe increased by 18%, while in 2017 there was a 2% increase in the number of installations compared to 2016. Biogas plants use various kind of feedstock, with dominating those from agriculture and the agri-food industry. It should be emphasized, that biogas has not always favorable emission parameters. The final emission throughout the whole life cycle of this energy carrier depends on many factors.

Greenhouse gas emissions of biofuels and bioenergy can be calculated using various methods [23]. However, in the case of biofuels and bioenergy, which can be counted towards the national and EU targets for renewable energy sources and qualified for public support systems, emissions throughout their life cycle must be calculated in accordance with the methodology given in the RED Directive. The Directive also sets out GHG emission reduction thresholds for equal energy carriers relative to their fossil comparators. Failure to meet these thresholds disqualifies such an energy carrier from the possibility of including them among the renewable energy targets. Considering above, energy carriers and raw materials for their production are sought that will have the lowest GHG emission in the whole life cycle. Biogas is one of such carrier. In his case, the structure of GHG emissions largely depends on what type of raw material is produced for biogas production and in what kind of tanks the digestate sludge is stored. If waste raw materials are used for biogas production, then GHG emission associated with their acquisition is assumed to be zero. In addition, when liquid manure is used as a raw material for biogas production, the bonus associated with the improvement of slurry management is entitled to the final emission. Such possibilities result directly from the RED directive. Greenhouse gas emissions for such raw materials are calculated only from the stage of their transport to the biogas plant. On the other hand, if dedicated energy crops, such as silage maize, are used for biogas production, the emission connected with their cultivation are added to the total GHG emissions. This emission are directly related to the use of fertilizers (mainly nitrogen) and plant protection products, field emissions of nitrous oxide and fuel combustion (mainly diesel) during the operation of agricultural machinery. The share of emissions associated with obtaining biomass in the total GHG emissions for electricity generation from biogas is significant and ranges from 25% to 35% [10]. In the case of digestate storage, the type of tank has a significant impact on greenhouse gas emissions. If these are closed tanks, then the methane released from the digestate is recovered and therefore does not constitute emissions to the atmosphere. If the open storage tanks are used, then this GHG are directly emited to the air and are included in the total gas balance. The possibility of emissions reduction depending on the raw material and assuming the use of closed tanks is from 29% to 65% compared to open tanks [10].

6. Nomenclature

EU – European Union
Eq – Equivalent
FFC – Fossil Fuel Comparator
GHG – greenhouse gases
IRENA – The International Renewable Energy Agency
LCA – Life Cycle Assessment
RED – Renewable Energy Directive
CO_2 – carbon dioxide
CH_4 – methane
N_2O – nitrous oxide

7. References

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