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Calculation of Greenhouse Gas Savings: Switch from Electricity Production to Biomethane. Case Study

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***Abstract* – Greenhouse gases are mainly comprised of carbon dioxide. In 2021, anthropogenic CO_2 emissions in the atmosphere have risen to 37.9 Gt, a 60 % increase from the levels observed in 1990. The production of high-value products using CO_2 can contribute to decreasing atmospheric CO_2 levels and advancing the objectives of the Green Deal. In Latvia, biofuel–biomethane production may also present a viable solution. Diversifying the energy sector, which can benefit the country's economy, is another advantage of this scenario. The study examines the transformation of a Latvian biogas production facility, which shifts towards producing biomethane as its final product. The study also involves the computation of greenhouse gas emission reductions resulting from utilizing biomethane instead of biogas in the network.**

***Keywords* – Biogas; biomethane; GHG; GHG calculation; fuel; Latvia.**

1. INTRODUCTION

Global warming and climate change are caused by greenhouse gases (GHGs). This problem is one of the most severe problems of our time. Greenhouse gases are a range of gases such as carbon dioxide (CO_2), methane (CH_4), nitric oxide (N_2O), as well as hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride (SF_6). Among them, carbon dioxide is the major. Adding to the complexity is the fact that CO_2 is an integral part of almost any technological process due to the use of fossil fuels [1]–[3].

In 2015, an agreement was adopted, the purpose of which is to fight climate change [4]. The main goal of the European Union is to become ultimately carbon neutral by 2050, with an intermediate goal of reducing greenhouse gases by at least 55 % by 2030 [5]. Such a task requires changes in many sectors, including the energy sector. According to the IEA report [6], in 2021, CO_2 emissions accounted for 89 % of total greenhouse gas emissions in the energy sector. Switching from fossil energy sources to renewable ones can reduce the share of carbon dioxide. Implementing CO_2 capture and/or use systems in the industry could also potentially benefit total emissions [7], [8]. As stated [8], CCS and CCU technologies can reduce carbon emissions by 20 %.

Two main ways of using carbon dioxide can be distinguished – its conversion into various products (for example, plastic [9], [10], and its use directly without modification [3]. Unlike using carbon dioxide directly, converting it is a more attractive option, as it allows getting valuable products, such as new chemical compounds (like carbon monoxide), as well as fuel

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[11], [12]. However, despite the opportunity to obtain a valuable product, converting carbon dioxide requires energy, which already creates CO_2 in itself [3].

Biomethane is a renewable gas that can be obtained from biogas purification (depending on the system, biogas can contain ~50 % methane (CH_4), which is classified as low-grade biogas) [13]. The purification process involves the removal of carbon dioxide, leaving pure methane. The resulting CO_2 is of sufficient purity to be sold or redirected to other industries (e.g., greenhouses, pharmacy, etc.), thus promoting CCU technologies. At the same time, increasing the CH_4 content in the mixture raises the calorific value of the gas, making fuel much more valuable. The leading technology for CO_2 removal is Pressure Swing Adsorption (PSA), which working principle is based on adsorption differences of components and reagents [13], [14]. Biomethane has characteristics similar to fossil natural gas, making it a potential substitute for this fuel. An additional plus is the ability to use the same equipment and infrastructure, as well as the 'compatibility' of these two gases – they can be safely mixed [15]–[18].

Latvia already has everything necessary for the development and further production of biomethane. The first biogas stations appeared in the country in the 1990s, and their main resource is biomass and agricultural waste. As of 2019, 53 biogas production stations were registered in the country; however, several stations were closed due to several financial and political decisions [19].

1.1. Advantages of Biomethane

Even though, at the moment, natural gas occupies up to a quarter of the world energy resource market [20], it has the lowest carbon footprint. The importance and necessity of other low-carbon gases are also increasingly recognized. Such gases can be biomethane produced in anaerobic processes, syngas, and even low-carbon hydrogen. The current production rate and the prices for the mentioned types of gas show the importance of their production in the future. Although the benefits of biomethane production often come down to financial considerations, it is essential to remember that biomethane production is also beneficial from an environmental and sustainability point of view, as the carbon footprint that is left behind the biomethane is much lower than it is for more conventional types of fuel [16], [21, [22].

Biogas and biomethane are both renewable gases that have the potential to help reduce greenhouse gases. Using biomethane in a network created for natural gas and its subsequent replacement does not require additional financial investments or the development of new and/or other infrastructure. The existing gas transport network in Latvia can already be used for biomethane. This fact is a critical condition in the fight against the reduction of emissions and decarbonization of the gas sector, which, in addition, can provide an affordable price for the consumer and bring diversification into the energy sector. Another advantage of biomethane is that it can be stored and produced permanently and constantly. This fact will balance intermittent energy from other renewable energy sources, such as windmills [23]–[26]. As a renewable energy source, biomethane can positively contribute to dealing with climate change. Reducing anthropogenic emissions is a complex task; therefore, every decision to reduce our impact on the climate is significant and tangible in the long term [3].

1.2. Carbon Cycle

Sustainable agriculture and methane production are closely linked to the carbon cycle and sustainable resource and energy management. During biogas production, digestate is created – a by-product of production- a valuable organic substrate rich in nutrients [27], [28]. Unlike

the raw materials used in biogas production, digestate can be used immediately as an organic fertilizer in the agricultural industry. Additionally, using such a fertilizer promotes the reuse of nutrients, returning them to the soil for enrichment and restoration and, thus, the replacement of mineral fertilizers [29].

Depending on the resource used, the biogas produced at the plant can contain up to 60 % biomethane. The remaining 40 % are products in the form of carbon dioxide [30].

Setting up the process correctly is essential to purify biogas completely of impurities like water and sulfides. These measures help achieve biomethane's highest quality and performance [31]. The use of carbon dioxide is the last step in the carbon cycle – a process that starts with the use of CO_2 in plants, which then becomes a resource for biogas production and is released to become a resource for the growth of new plants.

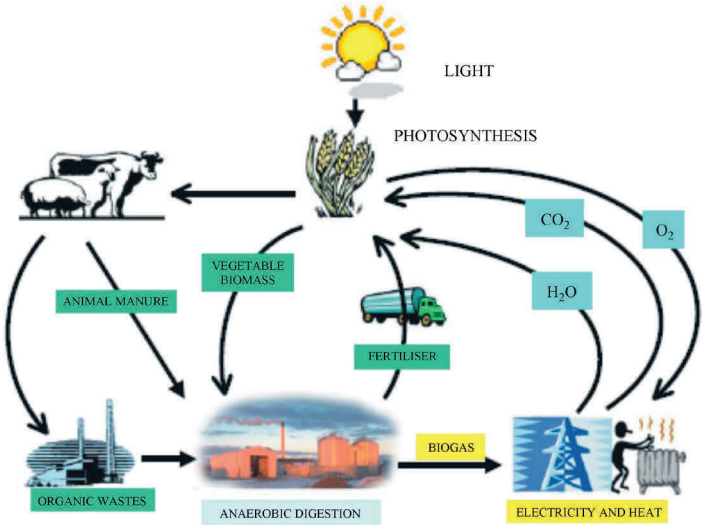

Fig. 1. Carbon cycle principle [32].

The European Union initiative [33] indicates the need for sustainable use of natural resources to increase efficiency in transitioning to a cyclical economic system through cooperation (synergy) of various sectors. Facilitating the policies and levers of the sectors involved can also positively impact the effectiveness of the implementation of a low-carbon economy, the use of renewable energy, efficiency measures, etc. Because biogas is produced from organic waste, this production complies with the basic principles of the circular economy (and the economy of circular energy) [34]. Biogas can be produced not only from waste from the agricultural sector but also from household and industrial waste. Additionally, wastewater can also be used as a resource, increasing its added value [35].

2. METHODOLOGY

The purpose of this paper is to analyse the Biogas plant's transition from biogas to the production of biomethane and its further implementation in the natural gas grid. The study contains calculations of this transition – GHG savings, considering the resource heterogeneity. This work did not account for the distance to the grid injection point. It is also assumed that the plant uses the Pressure Swing Adsorption (PSA) method for the transition

process, as it is effective and suitable for working with gas mixtures generated by non-homogenous feedstock [36].

2.1. Biogas Plant Case Study

The biogas station is located in the central region of Latvia, Zemgale, with 5500 people living in the area of the plant. The total area of the region is 311.6 km^2 (Fig. 2).



Fig. 2. Region of the location of the Biogas Plant [37].

According to [38] and a personal interview with the biogas station manager, in 2021, the station used just over 57 thousand tons of substrates. In total, 13 substrates were involved in the production – milk whey, sludge, chicken manure, beer yeast, grass silage, immature grain crops silage, maize silage, and spoiled grains (Table 1). This amount produced 5 621 708 Nm^3 of biogas during the specified period with a calorific value of 29 860.417 MWh. Biogas was used to produce 11 325.577 MWh of thermal energy and 11 619.62 MWh of electricity.

TABLE 1. SUBSTRATES AND THEIR QUANTITIES USED IN THE BIOGAS PLANT CASE STUDY IN 2021

Substrate	**Amount, t/year**	**Methane yield, Nm^3/t** [38]
Sediments of flotation from milk powder factory	3982.7	682.7
Milk whey	16 829.78	36.9
Sludge	8852.2	47
Chicken manure	5419.3	55.4
Beer yeast	169	505.8
Immature grain crops silage	852.4	54.6
Maize silage (2021)	15 258.3	106
Maize silage (2020)	3 602	106
Maize silage (2019)	12.3	106
Grass silage (2021)	803.4	100
Grass silage (2020)	612	100
Grass silage (2019)	513.4	100
Spoiled/immature grains	72	122.2
TOTAL	57 050.6	

2.2. GHG Savings Calculation

The calculation of greenhouse gases was carried out based on Directive 2018/2001/EU (REDII) [39], [40]. This directive is a continuation of REDI 2009, which sets out methods for controlling the sustainable and ecological production of biofuels. Additionally, a network of stakeholders, such as producers and consumers, has been established within REDI. To participate in such a network, each participant must obtain certification from REDcert and ISCC [41]. REDcert, in turn, is a quality assurance and assessment scheme for indicators such as sustainable production, traceability of documentation, etc. REDcert is accepted throughout Europe [42].

There are two ways to calculate the amount of greenhouse gases saved – actual value and default value-based [43]. Considering that the default method is based on a limited and specific type of resource for biogas (wet manure, dry manure, municipal public waste), the actual value-based calculation method of GHG savings was used in the work.

Eq. (1) shows the calculation of emissions in case of co-digestion of various substrates in biomethane production from biogas:

$$E = \sum_{1}^{n} S_n \cdot \left(e_{ec,n} + e_{td,\text{feedstock},n} + e_{l,n} - e_{sca,n}\right) + e_p + e_{td,\text{product}} + e_u - e_{ccs} - e_{ccr}\ , \qquad (1)$$

where

E Total amount of emissions from the biomethane production (before energy conversion), kg CO_2eq/ton;

S_n Share of feedstock (type n), in a fraction of input to the digester;

$e_{ec,n}$ Amount of emissions from the extraction / cultivation of feedstock (type n), g CO_2eq/MJ final product;

$e_{td,\text{feedstock},n}$ Amount of emissions from the transport of feedstock n to the digester, g CO_2eq/MJ final product;

$e_{l,n}$ Annual emissions from carbon stock changes due to land usage for feedstock type n, g CO_2eq/MJ final product;

$e_{sca,n}$ Emissions savings from improved agricultural management of feedstock type n, g CO_2eq/MJ final product;

e_p Emissions from processing, g CO_2/MJ final product;

$e_{td,\text{ product}}$ Emissions from transport and distribution of biomethane, g CO_2eq/MJ final product;

e_u Emissions from the fuel in use, g CO_2/MJ final product;

e_{ccs} Emissions savings from carbon capture and geological storage, g CO_2eq/MJ final product;

e_{ccr} Emission savings from carbon capture and replacement, g CO_2eq/MJ final product

Parameters e_{ec}, e_t, e_p, and e_u are calculated according to Eq. (2):

$$e_{ec}, e_{td}, e_p, e_u = \frac{\sum \text{amount of material input} \cdot \text{Emissions Factor of the material}}{\text{Yield or quantity of the material}} \qquad (2)$$

Eqs. (1) and (2) are the basis for the following calculations. Even though parameter e is calculated in [g CO_2/MJ of the final product (CH_4)], it is also recommended to calculate it per mass of the intermediate product (as [g CO_2/kg $V_{product}$]) and only at the end allocate the parameter to the final product.

3. RESULTS

Having the necessary data from a biogas production station, it is possible to calculate the greenhouse gas emissions generated by the station, as well as how much emissions will be saved if, instead of biogas, the station produces methane for its subsequent use in the city's power grid. Based on [43], a similar calculation was made for the observed Biogas Plant.

3.1. Calculation of Emissions Parameters

The $e_{ec,n}$ parameter only applies to maize silage, grass silage and immature grain crops. According to [44], the substrate with the least influence on the result may not be considered at this calculation stage, so substrate 'spoiled/immature grains' is neglected.

Table 2 lists the values for maize silage [45] that are needed to calculate the parameter e_{ec} (Eq. (2)). Similar calculations should be made for each substrate used in production. All values (emission factors, heating values, etc.) are taken from the European Commission schemes [45], [46].

TABLE 2. VALUES FOR THE MAIZE SILAGE [45], [46]

Substrate: Maize Silage	**Value**	**Emission Factor**
Seeds	30 kg/ha year	0.32 $kgCO_2eq/kg$
N fertiliser (mineral)	90 kg/ha year	6.41 $kgCO_2eq/kg$
N fertiliser (digestate)	10 kg/ha year	0.0075 $kgCO_2eq/kg$
CaO fertiliser	0 kg/ha year	0.89 $kgCO_2eq/kg$
M2O field emission	–	5.6 kgN_2O eq/ha year
Pesticides	NA	13.9 $kgCO_2eq/kg$
Diesel (machinery)	11 764.7 L/ha year	3.14 / 2.1 $kgCO_2eq/kg$
Maize yield (fresh matter)	37 820 kg/ha year	–

Thus, the three main substrates have the following effect in $kgCO_2eq$ per one kilogram and one ton of fresh matter (FM):

TABLE 3. THE E_C PARAMETERS FOR THE MAIN SUBSTRATES

Substrate	e_{ec}, **$kgCO_2eq/kg$**	e_{ec}, **$kgCO_2eq/t$ FM**
Grass silage	0.104	103.7
Immature grain crops	0.081	81.2
Maize silage	0.067	67.4

Biogas Plant does not do any of the soil carbon accumulation, like crops covering, improved manure management or composting for soil improvement. Thus, these parameters cannot account for emissions savings [47].

The parameter $e_{l,n}$ is the annual emission from the change in carbon stock. This change arises due to land use for the sake of the substrate n. In the case of the Biogas Plant, there were no changes; therefore, $e_{l,n} = 0$.

Similar values will be for the parameters e_{ccs}, e_{ccr}, $e_{sca,n}$. During the period under review, no improvements or upgrades were made to the agricultural feedstock management system at the station, and no CO_2 capture and storage system was installed.

In turn, the $e_{td,\ \text{feedstock},n}$ parameter shows the emissions from resource transportation to the digester and is calculated by Eq. (3):

$$e_{td,\text{feedstock},n} = \frac{(d_l \cdot f_l) + (d_e \cdot f_e) \cdot EF}{\text{Amount of transported substrate}} \quad (3)$$

where

d_l Distance travelled while loaded, km;
d_e Distance travelled while empty, km;
f_l Fuel consumption loaded, L/km;
f_e Fuel consumption empty, L/km.

Biogas Plant works with different substrates; therefore, the parameter must be calculated for each. The type of fuel used should also be considered since the emission factor (EF) depends on it. For diesel, for example, the EF is 3.14 $kgCO_2eq/l$ (Table 4).

TABLE 4. SUBSTRATE TRANSPORT PROCESS

	Value	Unit
The volume of transported biomass	5491.25	t
Distance (loaded)	4	km
Distance (empty)	4	km
Fuel consumption (loaded)	0.41	L/km
Fuel consumption (empty)	0.24	L/km

Having data on logistics and using Eq. (3), we get that the $e_{td,\text{feedstock},n}$ parameter for the station is 0.0015 $kgCO_2eq/t$ for one type of substrate. The total GHG emissions of all 13 substrate types equals 1.96 $kgCO_2eq/t$.

3.2. Emissions from Processes on the Biogas Plant

The next step is to determine the emissions from the processes at the biogas plant for a period of one year. For this parameter – e_{p1}, it is required to know the amount of energy spent on biogas production, as well as the loss of methane (Table 5).

TABLE 5. MAIN PROCESSES ON THE PLANT AND THEIR VALUES

	Value	Unit
Electricity	11 619 000	kWh/year
Process heat	11 325.58	MJ/year
Methane yield	5 621 708	Nm^3/year
Methane loss	562 170.8	Nm^3/year
Digestate	43 000	t/year

According to RED and ISCC certification systems [43], [48], if a special gas-tight lid for storing digestate is installed at the biogas station, the loss of methane is reduced and can be assumed to be ~1 %. These covers are installed at the observed Biogas Plant, so in further calculations, methane losses will be taken as 1 %.

Each resource used – electricity and heat – also has its own emission factor (Table 6):

TABLE 6. EMISSION FACTOR FOR ELECTRICITY AND HEAT USAGE

Input	Emission Factor	Unit
Electricity mix	0.19	$kgCO_2eq/kWh$
Heat (CHP Unit)	0.61	$kgCO_2eq/MJ$
Methane	23	$kgCO_2eq/kgCH_4$

Using Eq. (4), we can calculate the parameter e_{p1}:

$$e_{p1} = \frac{(\text{Electricity} \cdot EF_E) + (\text{Heat} \cdot EF_h) + (\text{Methane loss} \cdot EF_m)}{\text{Total methane yield}}, \quad (4)$$

where

EF_E Emission factor from electricity, kg CO_2eq/kWh;

EF_h Emission factor from heat, kg CO_2eq/MJ;

EF_m Emission factor from methane, kg $CO_2eq/kg\ CH_4$.

Substituting the required values from Table 6 shows that parameter ep_1 for the Biogas Plant equals 2.70 $kgCO_2eq/m^3CH_4$.

Next, it is necessary to calculate the emissions from the biogas treatment process and its supply to the system (e_{p2}). Biogas processing is the last stage of its production. It is this stage that includes the transfer of biogas to biomethane. Similar to the previous step, emissions from processing biogas to biomethane should take the biomethane yield per year, regardless of the amount of biomethane subject to further certification [43].

For the Biogas Plant, the biogas treatment process requires the following investments (Table 7):

TABLE 7. REQUIRED INPUT FOR THE BIOGAS TREATMENT

	Value	Unit
Methane input	5 621 708	Nm^3/year
Methane slip (in PSA)*	1–5	%
Methene loss	562 170.8	Nm^3/year
Electricity**	994 462.8	kWh/year
Process heat	0	MJ/year
Biomethane output***	4 735 537.2	Nm^3/year

Note: *PSA – Pressure Swing Adsorption, biogas treatment technology
**0.21 kWh/m^3 multiplied by biomethane output;
*** Methane input minus the 1 % of methane loss in the biogas plant

Thus, the parameter e_{p2} is calculated by the Eq. (5):

$$e_{p2} = \frac{(\text{Electricity for } PSA \cdot EF_E) + (\text{Heat for } PSA \cdot EF_h) + (\text{Methane loss} \cdot EF_m)}{\text{Biomethane output}} \quad (5)$$

Since biomethane will be used in the network in the future, it is necessary to know the emissions obtained during its transportation and distribution. The biogas processing plant must check the savings potential of the biomethane that will be put into circulation. This means identifying emissions from the stages of compression and transport of biomethane through natural gas networks, as well as compression of biomethane at a particular station, to make sure that the final product meets the requirements of this station (Table 8).

TABLE 8. REQUIRED ENERGY INPUT AND EMISSION FACTOR FROM THE DISTRIBUTION

Input of energy	**Value**	**Unit**
Electricity (transport in the natural gas grid)	0.003	kWh/m^3
Heat process	0.058	MJ/m^3
Electricity (compression in the filling station)	0.164	kWh/m^3
Biomethane distribution, emission factors		
Electricity mix	0.192	kgCO_2eq/kWh
Heat process	0.067	kgCO_2eq/kWh

Using the data from Table 8, it is possible to calculate the emissions themselves from gas transportation through the network:

$$e_{td,\text{product}} = (ET_{\text{ng}} \cdot EF_{\text{e}}) + (HT_{\text{ng}} \cdot EF_{\text{h}}) + (EC_{\text{st}} \cdot EF_{\text{st}}), \tag{6}$$

where

ET_{ng} Electricity for biomethane transport in the natural gas grid, kWh/m^3;
EF_{e} Emission factor for electricity for biomethane transport in the natural gas grid, kWh/m^3;
HT_{ng} Heat for biomethane transport in the natural gas grid, MJ/m^3;
EF_{h} Emission factor for heat process for biomethane transport in the natural gas grid, kgCO_2eq/kWh;
EC_{st} Electricity for biomethane compression in filling station, kWh/m^3;
EF_{st} Emission factor for electricity for biomethane compression in filling station, kWh/m^3.

Substituting all the data into the formula, we get that the Biogas Plant for the transportation and compression of biomethane at the station produces 0.036 kgCO_2eq/m^3. If there is no compression, then $e_{td.\text{product}}$ = 0.043 kgCO_2eq/m^3.

3.3. Substrate Allocation

An important calculation step is substrate allocation. Many different substrates are used in biomethane production – each of them must be analysed separately for the considered period. It is recommended for biogas producers to write down how much methane can be obtained from each substrate.

For a correct calculation of biomethane yield from each substrate, the number of tons of each substrate delivered to the biogas station must be multiplied by 10 % – losses that, according to certification systems (REDcert and ISCC) usually occur and, therefore are taken into account.

At this stage, the first step is to multiply the amount of substrate by the percentage of losses (10 %), thus obtaining the total amount of substrate according to the estimated losses. Further, using Eq. (7), the proportion of methane in each type of substrate is calculated [45], [46]:

$$\text{Share of } CH_4 \text{ yield} = \frac{\text{Amount of substrate after } 10\,\% \text{ loss} \cdot CH_4 \text{ yield of the substrate}}{\text{Total } CH_4 \text{ yield (calculated) in the biogas plant}} \cdot 100\,\% \tag{6}$$

Thus, the following values are typical for the substrates used at the Biogas Plant (Table 9):

TABLE 9. METHANE YIELD FOR EACH KIND OF USED SUBSTRATE [45], [46]

Substrate	**Amount (before losses), t/year**	**Input after losses, t/year**	**Methane yield, Nm^3/t FM [44], [49]**	**Share of methane yield in each substrate, %**
Sediments of floatation milk powder factory	3982.7	3584.4	628.7	36.5
Milk whey	186 829.7	15 146.7	36.9	9.1
Sludge	8852.2	7966.7	47	6.1
Chicken manure	5491.3	4924.1	55.4	4.4
Beer yeast	169	152.1	505.8	1.3
Immature grain crops sludge	852.4	767.2	54.6	0.7
Maize silage (2019)	15 258.3	13 732.5	106	23.6
Maize silage (2020)	3602	3241.8	106	5.6
Maize silage (2021)	12.3	11.07	106	0.02
Grass silage (2019)	803.4	723.1	100	1.2
Grass silage (2020)	612	550.8	100	0.9
Grass silage (2021)	513.4	462.1	100	0.7
Spoiled/immature grains	72	64.8	122.2	0.1
Total methane yield calculated, Nm^3		6 179 378.3		

3.4. Total amount of Emissions

Now that the proportion of methane yield in each substrate has been found, it is necessary to allocate this proportion (%) to the total calculated biomethane yield (total methane minus 1 % losses according to REDcert and ISCC) [43], [48], [50]:

$$\text{Total usable amount of biomethane} = \text{Proportion of methane yield} \times \text{Total biomethane output} \quad (7)$$

For the Biogas Plant, each type of substrate can produce the following amount of biomethane (Table 10):

TABLE 10. TOTAL USABLE AMOUNT OF BIOMETHANE PER EACH SUBSTRATE

Substrate	**Share of methane yield in each substrate, %**	**Total usable amount of biomethane, Nm^3/year**
Sediments of floatation milk powder factory	36.47	1 726 965.09
Milk whey	9.05	428 320.94
Sludge	6.06	286 956.36
Chicken manure	4.43	209 820.52
Beer yeast	1.25	58 956.61
Immature grain crops sludge	0.68	32 099.85
Maize silage (2019)	23.56	1 115 525.28
Maize silage (2020)	5.56	26 339.83
Maize silage (2021)	0.02	899.25
Grass silage (2019)	1.17	55 411.36

Grass silage (2020)	0.89	42 210.30
Grass silage (2021)	0.75	35 409.75
Spoiled/immature grains	0.13	6068.35

After acquiring the values of the parameters e_{ec}, $e_{td,\text{feedstock},n}$, e_{p1}, e_{p2} and $e_{td,\text{product}}$, for each substrate used, these values are summed up for use in the following formula to determine the total emissions based on 1 Nm^3 of biomethane:

$$\text{Total emissions per m}^3\text{ biomethane} = \frac{(e_{ec} + e_{td,\text{feedstock},n} + e_{\text{p1}} + e_{\text{p2}} + e_{td,\text{product}})}{\text{Total usable amount of biomethane}} \quad (8)$$

Knowing that for the observed Biogas Plant, the sum of all parameters for all substrates is 25 246 762.29 $kgCO_2eq$/year, and the total amount of biomethane is 4 261 983.48 Nm^3/year, using Eq. (8) it has been determined that the total number of emissions is 5.92 $kgCO_2eq/m^3$.

According to REDII [40], greenhouse gas emissions from biomass-derived fuels must be expressed in grams of CO_2 equivalent per MJ of biofuel (gCO_2eq/MJ). For recalculation, the lower heating value of biomethane is used:

$$\text{Total emissions per MJ biomethane} = \frac{\text{Total emissions per m}^3\text{ of biomethane}}{\text{Heating value of biomethane}} \times 100 \quad (9)$$

The lower heating value of biomethane is 36 MJ/m^3, resulting in 16.45 gCO_2eq/MJ emissions.

3.5. GHG Savings Calculation

The last step is to calculate the directly stored emissions from biomethane. According to the Directive of the European Union 2018/2001 [43], the Member States of the European Union have the right to produce only that biomethane, the greenhouse emissions of which do not exceed the established value of 24 gCO_2eq/MJ. This value is based on a fossil fuel comparator, E, as well as a minimum allowable emission retention value of 35 %.

Eq. (10) is used to calculate the stored emissions from biomethane:

$$\text{Saving} = \frac{(E_{\text{F}(t)} - E_{\text{B}})}{E_{\text{F}(t)}} \cdot 100\,\% \quad (10)$$

where

E_{B} Total emissions from biomethane, gCO_2eq/MJ CH_4;

$E_{\text{F}(t)}$ Total emissions from fossil fuel comparator, gCO_2eq/MJ.

In the case of the Biogas Plant, the number of emissions saved is 80.36 %. However, this value reflects the rate of 1 % loss. According to REDcert, PSA losses can be as high as 5 %. Thus, the smallest number of saved emissions is 76.34 %.

4. CONCLUSION AND DISCUSSION

In this paper, a Latvian Biogas Plant case study was carried out to determine the amount of emissions saved from biomethane production. The actual value method offered by REDcert was used for calculations. These calculations help determine the potential environmental benefits of switching from biogas production to biomethane.

All calculations were performed based on the rules of the method and took into account all the substrates used at the station, the main ones being maize silage, grass silage, sludge, milk whey, and manure. The calculations were based on standard resource data (i.e., emission factor), and therefore the technique is suitable not only for analysis

The calculations also considered the recommended assumption of 1–5 % losses in the PSA technology from using biomethane. At the minimum value, the losses of emissions savings for the plant amounted to 80.34 %, while the worst-case scenario (5 %) showed 76.34 % of GHG savings.

This method of calculation can be time-consuming since it is necessary to calculate the number of emissions for each substrate used. It is also required to strictly follow each step because skipping them can distort the final result.

According to the requirements of the European Union, specified in REDcert, starting from 2017, the conservation of emissions for biogas plants using a mixture of different substrates for production should not be less than 50 %. Otherwise, this project will not be considered successful. However, the Biogas Plant is an excellent example of a successful transition from biogas to biomethane. Thus, the station can become a carbon neutral project and part of the Decarbonized Regional Development projects aimed at reducing greenhouse emissions in Latvia.

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