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Amount of manure used for biogas production

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Abstract. Methods for calculation of the amount of manure from every agricultural animal species and subgroup for production of biogas have been developed in compliance with the 2006 IPCC Guidelines. These methods can be applied for future forecasts if the amount of biogas produced in the country increases. It has been stated that in 2013 in Latvia for production of biogas mostly chicken and pig manure was used – correspondingly 33.7% and 26.7% from the amount of manure obtained from these animals. In the forecast for 2020, in turn, it is expected that the consumption of manure will be 31.9% of chicken manure and 31.5% of pig manure, from the amount of manure obtained from the corresponding group of animals.

Key words: biogas, manure, 2006 IPCC Guidelines.

INTRODUCTION

At present there are 53 biogas plants operating in Latvia and their total capacity exceeds 54 MW. According to the renewable energy development forecasts in the country, it has been planned to build 89 plants with the total capacity 130 MW by 2030 (VARAM Infozin_Biogāze_09012013).

The most important raw material for production of biogas is animal manure, corn silage, animal feed residue and biomass of other kinds. Nevertheless, the main attention is paid to the usage of manure as it reduces emissions of methane and nitrogen in the surrounding atmosphere thus decreasing the formation of the greenhouse effect emissions in the atmosphere. Besides, in the result of manure recycling biogas and digestate are obtained. Biogas is used for production of heat and electric energy, but digestate is not smelly and can be used for fertilization of soil as it contains all main biogenic elements (N, P, K). Besides, N has obtained a form of ammonium that can be more easily used by plants (Dubrovskis & Adamovičs, 2012).

It has to be noted that reduction of greenhouse gas emissions is one of the main purposes why the state supports the development of biogas production, at the same time requiring that at least 30% of the biomass used for production of biogas is manure (Regulations of the Cabinet of Ministers, No.268).

The aim of the present research is to state the proportion of manure used for production of biogas from every corresponding agricultural animal species in Latvia. It is necessary for preparation of annual state inventory reports on greenhouse gas emissions as well as for future forecasts about the necessary consumption of biomass with production of biogas increasing.

MATERIALS AND METHODS

At present, there is information available in Latvia on the kind and amount of biomass used for production of biogas. But these data do not specifically indicate what the distribution of manure along separate farm animal groups for production of biogas is in accordance with the 2006 IPCC Guidelines (IPCC Guidelines for National Greenhouse Gas Inventories, 2006). Besides, according to these data there are problems with forecasting biomass consumption in future, especially because the kinds and amounts of definite biomass have a tendency to change.

To achieve the aim of the investigation, two methods were developed: the first – for calculation of the proportion of manure for production of biogas according to the obtained statistical data on a definite year, for example, last year; the second – for future forecasts of the used part of manure for production of biogas, i.e., for stating of the amount of this biomass in any of the future years according to the biogas production development plan.

The first method – stating of the proportion of manure used for production of biogas according to the statistical data

For production of biogas, different kinds of biomass can be used, but on animal farms for this reason the following is used: cattle manure, pig manure, poultry manure and grass (mainly corn) silage. Besides, the Rural Support Service has summarised information on the consumed amount of every kind of biomass. Nevertheless, this distribution does not comply with the 2006 IPCC Guidelines as considerably more detailed distribution of the used manure for production of biogas among the farm animal subgroups is determined in these guidelines (Table 1).

Table 1. Classification of cattle, pigs and poultry according to the animal classification determined in 2006 IPCC Guidelines

Animal groups	Animal subgroups	Explanation
Cattle	Adult milk cows	First-calvers or older cows, including dry cows
	Suckling cows, breeding bulls	Cattle reached breeding age
	Young stock	Calves, heifers, feedlot young stock
Pigs	Hogs	All kinds of sows, boars
	Young pigs	Weanings, feedlot stock, young sows, young boars
Chicken	Laying hens*	Handling in cage batteries
	Chicken and poulets	Handling in cage batteries

*for handling laying hens, chicken and poulets also other solutions can be used but in that case poultry manure is not used for production of biogas

To calculate the percentual proportion of the manure used for biogas production from every group of farm animals, the total amount of manure obtained from every corresponding group of animals used for production of biogas has to be known.

Therefore, this proportion can be calculated according to the following formulae (1)–(3):

$$\lambda_l = \frac{M_{bl}}{\sum M_l} \cdot 100 \quad (1)$$

$$\lambda_c = \frac{M_{bc}}{\sum M_c} \cdot 100 \quad (2)$$

$$\lambda_p = \frac{M_{bp}}{\sum M_p} \cdot 100 \quad (3)$$

where: λ_l, λ_c, λ_p – percentual amount of cattle, pig and poultry manure used for production of biogas, %; M_{bl}, M_{bc}, M_{bp} – amount of cattle, pig and poultry manure used for production of biogas, t/year; $\sum M_l$, $\sum M_c$, $\sum M_p$ – total amount of cattle, pig and poultry manure, t year^{-1}.

The second method – forecasting of manure proportion necessary for production of biogas

In order to forecast the consumption of manure for production of biogas in the nearest future years the amount of the planned biogas or produced electric energy as well as the number of animals the manure of which will be used for production of biogas have to be known. For this reason the calculation can be divided in several stages.

1. The necessary amount of dry matter in manure for production of biogas is calculated, tsd.t year^{-1}

$$M_{s.nep} = \frac{b_k \cdot (1 - b_{at}) \cdot Q_{b.en}}{q_{gs} \cdot E_g \cdot k_{el}} \quad (4)$$

where: b_k – proportion of manure used for production of biogas; b_{at} – coefficient showing the proportion of biogas produced from waste, b_{at} ~ 0,4 (VARAM Infozin_Biogāze); $Q_{b.en}$ – amount of electric energy to be produced from biogas per year (according to the energetics forecast data), GWh; q_{gs} – average weighed biogas output from the used biomass, m^3 t^{-1}; E_g – heat capacity of biogas.

If the content of CH_4 in biogas is ~ 60%, then E_g ~ 6 kWh m^{-3} (Dubrovskis & Adamovičs, 2012); k_{el} – coefficient showing what part of the obtained biogas heat capacity is turned into electric energy. According to literature (Dubrovskis & Adamovičs, 2012) k_{el} ~ 0,4.

According to the requirements of the Cabinet of Ministers Regulations No. 268 manure must comprise not less than 30% of the biomass for production of biogas. But it can be made more precise by calculation based on the statistical data

$$b_k = \frac{M_{bl} + M_{bc} + M_{bp}}{M_{bl} + M_{bc} + M_{bp} + M_{bsk}} \quad (5)$$

where M_{bsk} – amount of silage used for production of biogas in the corresponding year, t year^{-1}.

The average weighed biogas output q_{gs}, using the corresponding biomass can be calculated as follows

$$q_{gs} = \frac{q_l \cdot M_{bl} \cdot S_l + q_c \cdot M_{bc} \cdot S_c + q_p \cdot M_{bp} \cdot S_p + q_{sk} \cdot M_{bsk} \cdot S_{sk}}{M_{bl} \cdot S_l + M_{bc} \cdot S_c + M_{bp} \cdot S_p + M_{bsk} \cdot S_{sk}} \quad (6)$$

where: q_l, q_c, q_p – average weighed biogas output from cattle, pig and poultry manure dry matter correspondingly, m^3 t^{-1}; q_{sk} – average weighed biogas output from silage dry matter, m^3 t^{-1}; S_l, S_c, S_p – content of cattle, pig and poultry manure dry matter used for production of biogas, %; S_{sk} – average silage dry matter content used for production of biogas, %.

2. The amount of manure dry matter that is necessary for biogas production from every group of animals is calculated considering the statistical data on the amount of cattle, pig and poultry manure used in production of biogas.

$$M_{s.l} = \frac{M_{bl} \cdot S_l}{M_{bl} \cdot S_l + M_{bc} \cdot S_c + M_{bp} \cdot S_p} \cdot M_{s.nep} \quad (7)$$

$$M_{s.c} = \frac{M_{bc} \cdot S_c}{M_{bl} \cdot S_l + M_{bc} \cdot S_c + M_{bp} \cdot S_p} \cdot M_{s.nep} \quad (8)$$

$$M_{s.p} = \frac{M_{bp} \cdot S_p}{M_{bl} \cdot S_l + M_{bc} \cdot S_c + M_{bp} \cdot S_p} \cdot M_{s.nep} \quad (9)$$

where: $M_{s.l}$, $M_{s.c}$, $M_{s.p}$ – necessary amount of cattle, pig and poultry manure to be used in production of biogas, tsd. t year^{-1}.

3. The amount of manure dry matter obtained in a year from every separate group of animals is calculated: cattle

$$M_{i.s.l} = \frac{z_g \cdot S_g \cdot m_g}{100 \cdot 1000} + \frac{z_n \cdot S_n \cdot m_n}{100 \cdot 1000}, \quad (10)$$

pigs

$$M_{i.s.c} = \frac{z_c \cdot S_c \cdot m_c}{100 \cdot 1000}, \quad (11)$$

poultry

$$M_{i.s.p} = \frac{z_p \cdot S_p \cdot m_p}{100 \cdot 1000}, \quad (12)$$

where: $M_{i.s.l}$, $M_{i.s.c}$, $M_{i.s.p}$ – amount of manure dry matter obtained from cattle, pigs and poultry, tsd.t year^{-1}; z_g, z_n, z_c, z_p – planned number of milk cows, suckling cows and other adult cattle, pigs and poultry in the corresponding year, tsds; S_g, S_n – average dry matter content of milk cow, suckling cow and other adult cattle manure, %; m_g – average manure outcome from one milk cow, t year^{-1}; m_n, m_c, m_p – average weighed manure outcome from one suckling cow and all kinds of young stock, from pigs of all ages and poultry, t anim year^{-1}.

4. Proportion of the amount of manure to be used for production of biogas from every group of animals is determined: cattle

$$\lambda_l = \frac{M_{s.l}}{M_{i.s.l}} \cdot 100, \quad (13)$$

pigs

$$\lambda_c = \frac{M_{s.c}}{M_{i.s.c}} \cdot 100, \quad (14)$$

poultry

$$\lambda_v = \frac{M_{s.v}}{M_{i.s.v}} \cdot 100. \quad (15)$$

RESULTS AND DISCUSSION

To explain the procedure of calculation of the amount of manure necessary for production of biogas considering the 2006 IPCC Guidelines, the two above mentioned methods will be discussed: the first – calculating the proportion of manure for production of biogas in Latvia in 2013, the second – forecasting of this proportion for 2020.

Determination of the proportion of manure for production of biogas according to the statistical data

According to the data of the Latvian Rural Service, there were biogas production plants operating on 37 Latvian rural farms in 2013. Information on biomass used for production of biogas is summarized in Table 2.

Table 2 shows the amount of biomass of every kind of manure and the average of dry matter. Multiplying these parameters the amount of the corresponding biomass dry matter is obtained.

Table 2. Biomass used for production of biogas and proportion of manure used for this purpose considering the amount of dry matter

Raw material used	Amount, t year^{-1}	Average dry matter content,%	Amount of dry matter, t year^{-1}
Cattle manure	395,150	10	39,515
Pig manure	130,000	8	10,400
Poultry manure	27,050	30	8,115
Grass silage	1,056,600	Total	58,030
Total	1,608,800		

The next step is calculation of the manure output from separate groups of animals according to the classification in the 2006 IPCC Guidelines. For this purpose Table 3 is developed.

Table 3. Total amount of manure obtained in Latvia in 2013 from separate animal groups and subgroups

Animal group and subgroup	Number of animals *	Manure outcome, tsd. t year^{-1}				Consumption for biogas, %
		per 1 animal **	total	total in subgroup	total in group	
Cattle						
Milk cows	164,000	0.019	3,116	3116		
Suckling cows and other adult cattle	57,000	0.011	627	627	5,343.7	7,4
Calves up to the age of one year	109,300	0.005	549.5	1,603.7		
Young stock from 1 to 2 years	75,300	0.014	1,054.2			
Pigs						
Adult sows	43,300	0.0025	108.3	110		
Breeding boars	700	0.0025	1.8			
Pigs up to the age of 2 months	87,100	0.0003	26.1			
Pigs up to the age of from 2 to 4 months	108,100	0.0006	64.9	376.2	762.09	26,7
Feedlock stock and breeding young pigs	142,600	0.002	285.2			
Poultry						
Laying hens (starting from the age of 17-20 weeks)	2,430,500	0.00003	72.9	72.9	80.2	33,7
Chicken and poulets	750,000	0.00001	7.5	7.5		

Sources: *Central Statistical Bureau of the Republic of Latvia
**Regulations of the Cabinet of Ministers No.834.

In the first column of the table, more detailed classification of animal groups is given compared to the 2006 IPCC Guidelines, as it corresponds more precisely to the data on the number of agricultural animals in the corresponding year published by the Central Statistical Bureau of the Republic of Latvia. Besides, it makes it easier to calculate the amount of the obtained manure as it corresponds more precisely to the outcome of manure calculating per one animal that is determined in the Regulation No. 834 of the Cabinet of Ministers.

Calculation is started with stating the manure outcome from the animals of every subgroup mentioned in the table by multiplying the number of the corresponding animals with the corresponding manure outcome from one animal.

After that the calculated manure outcomes are summarized from the rows that correspond to one animal subgroup in accordance with the 2006 IPCC Guidelines and the total amount of the obtained manure in every animal subgroup and group is calculated.

At last, the amount of manure from every farm animal group necessary for production of biogas (second column of Table 2) is divided by the amount of manure obtained in this group of farm animals (Table 3) and the result is multiplied by 100 to get the result in per cents.

Forecast of the proportion of manure necessary for production of biogsas

In order to forecast the amount of manure necessary for production of biogas from every subgroup of agricultural animals, the manure biomass dry matter amount necessary for production of biogas has to be calculated.

Using the formula (5) the coefficient b_k of the portion of manure used for production of biogas is calculated which in the given case is 0.34. After that, using Table 2 and the information published in literature (Dubrovskis, Adamovičs, 2012) about the average biogas outcome from cattle, pig and poultry manure dry matter, the average weighed biogas output from biomass dry matter q_{gs} = 440 m^3 t^{-1} is calculated using the formula (6).

`Also the forecasts that in Latvia in 2020 the total capacity of biogas production equipment will reach 92 MW, published in the VARAM informative report, as well as the data of the Ministry of Agriculture on the number of planned agricultural animals (Table 4) are used.

Table 4. Calculation input data for 2020

Farm animal groups	Planned number	Average weighed manure outcome, t year-^{1} from one animal	Average manure dry matter content, %
Milk cows	190,000	19	10
Cattle (beef)	290,000*	6**	15
Pigs	500,000*	1.27	8
Poultry	5,200,000*	0.025	30

*including all animals up to the breeding age
**considering the pasture period

Table 4 shows the average weighed manure outcome and the content of dry matter from the animals of the corresponding groups. Using formulas (7)–(9) the manure dry matter content that in a definite year is necessary for production of biogas from every group of animals as well as the total amount of the corresponding manure to be obtained in that year can be calculated, formulas (10)–(12), and the obtained results are shown in Table 5. After that using formulas (14)–(16) the necessary proportion of manure for every corresponding subgroup of animals for production of biogas is calculated (last column of Table 5).

Table 5. Forecast results for 2020

Farm animal groups	Total obtained manure dry matter content, tsd.tons year^{-1}	Proportion of manure necessary for production of biogas from the corresponding group of animals, %
Cattle	622	9.7
Pigs	50.8	31.5
Poultry	39	31.9

The results of the calculations show that in 2020 approximately 89 thousand tons of manure dry matter are necessary for production of biogas, and the necessary amount of manure from separate animal groups to ensure it can be seen in Table 5.

The obtained results prove that based on the prognosticated data for production of biogas in 2020 mostly pig and poultry manure will be used, 31.5% and 31.9% respectively from the total obtained amount. Besides, the consumption of pig manure will increase by 18% in 2020.

In accordance with our unpublished research on the largest pig farms in Latvia, the obtained pig manure is stored mainly in anaerobic lagoons, but the amount of greenhouse gas emissions from such lagoons is almost three times higher than from the digestate obtained in biogas production plants. Therefore, expansion of biogas production using pig manure is highly important for decreasing the total greenhouse gas amount emitted by the production of animal breeding products.

CONCLUSIONS

To state the proportion of manure consumed for production of biogas from every corresponding group of farm animals in accordance with the 2006 IPCC Guidelines, statistical data on the amount of biomass used for production of biogas as well as on the number of farm animals and their classification in separate subgroups shall be obtained.

If it is necessary to forecast the consumption of manure needed for production of biogas in the nearest future, apart from the planned number of animals, data on the amount of biogas to be produced or the amount of electric energy produced from it, are required.

Applying the methods described in the article, it has been stated that in 2013 in Latvia mostly poultry manure was used – 33.7% of the total amount as well as pig manure – 26.7% of the total amount for production of biogas. The forecasts for 2020 are similar, as the planned consumption of poultry manure is 31.9% but of pig manure – 31.5% of the total amount of manure obtained from the corresponding animal subgroups.

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