Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 18, Issue 4, 2018
PRINT ISSN 2284-7995, E-ISSN 2285-3952

DEVELOPMENT OPPORTUNITIES FOR BIOGAS PRODUCTION FROM ANIMAL MANURE IN LITHUANIA

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Abstract

Biogas production from animal manure offers many environmental, agricultural, energy security, and social-economic benefits. The growth of biogas from animal manure in Lithuania is limited. Currently, there are only 10 biogas plants in operation that have been installed on large-scale pig farms. This study aimed to evaluate development opportunities for biogas production from animal manure in Lithuania. In order to achieve this aim, the total amount of animal manure generated in the country over the last year was estimated and the views and opinions on biogas production from animal manure of Lithuanian large-scale livestock farmers and representatives of agricultural holdings were investigated by conducting a survey. The total amount of animal manure in Lithuania was estimated to be 11.4 million tonnes in 2017. The results of the survey revealed that the level of awareness of biogas technology and economy, and support schemes for biogas among the potential biogas plant operators was low. The possibility to produce the own energy and complaints by local residents about animal manure management were identified as the main motives for installing biogas system on farms. The belief that investment is needed to solve some other problems on farms was found as the major obstacle for installing biogas system on farms.

Key words**:** *animal manure, biogas production, large-scale livestock farms, biogas plant, Lithuania*

INTRODUCTION

The expansion of biogas production from animal manure is affected by environmental goals, renewable energy, and bioeconomy issues expressed in the European Union's (EU) strategic documents [5; 6; 7; 8]. Apart from the fact, that, in the EU, primary energy production from biogas has increased significantly in the last decade (from 4,461 ktoe in 2006 to 16,600 ktoe in 2016) [9], animal manure provides only a small share of biogas production (7% in 2014) [14]. It is generally acknowledged that the largest potential for biogas growth is in making more use of animal manure [14]. In the EU, the potential of biogas production from animal manure is considerable [4; 12; 13; 19].

Biogas production from animal manure is recognized as being a concept of multifunctional character that is able to offer a wide range of benefits for the agricultural and energy sectors, environment, and society [2]. These benefits include the following [10; 12; 16; 17]:

-production of renewable energy;
-reduction of greenhouse gas emissions by substituting fossil fuel energy use and by capturing methane gas from animal manure;
-improvement of animal manure management and nutritional uptake efficiency;
-considerable reduction of odours;
-inactivation of pathogens;
-lesser air and water pollution;
-additional income for farmers;
-money savings for farmers;
-new job opportunities in rural areas when building and operating biogas plants;
-improvement of rural economies.

Different stakeholders (e.g. agricultural companies, farmers, energy generators/providers, policy makers, scientific researchers, environmental activists, regulators, local residents) have different attitude on agricultural, environmental, economic, and social benefits of biogas, which in turn influence their decision-making processes [18]. Despite the broad consensus among stakeholders on the need to develop biogas production from animal manure on

farms, the implementation of biogas projects falls mostly on farmers and agricultural companies. In recent years, several studies have been conducted in different countries aimed to identify motivational factors and barriers which underlie farmers' reasons for and for not adopting biogas technology on farms [3; 11; 18; 21; 22].

The outcomes of the survey conducted in Austria revealed that the main motives leading farmers to invest in biogas plants on their farms were: improvement of manure; possibility to produce the own energy; and diversification of farm income [22]. The results of the survey which was carried out in Austria, Bulgaria, Germany, Denmark, Spain and Poland indicated that the major hindrances for organic farmers to introduce sustainable organic biogas production included financial constraints and little knowledge about best practice examples [3]. The findings of the survey performed in England showed that the benefits from installing biogas technology on farms in terms of importance were seen by all interviewed farmers as improving farm profit and reduce pollution/contamination risk, whereas the most important potential obstacles put forward by farmers were establishment costs seem too high and the returns seem too low [21]. The results of the survey conducted in Czech Republic uncovered that the main motivational factors for adopting some renewable energy (including biogas) enterprises as reported by farmers were: diversification of agricultural activities and stabilization of farm income; landscape management; legislative and financial support. Constant changes in the legislation, unclear and complex legislation, and unprofitable production of renewable energy had been reported as the main barriers for adopting some renewable energy enterprises [11].

The livestock sector historically and traditionally has been, and remains, one of the most important agricultural activities in Lithuania. Livestock production generates animal manure which is considered as an organic fertilizer but often treated as an inevitable waste. Therefore, biogas production from animal manure provides a possibility to manage waste problems, while offering many other benefits.

The biogas production from animal manure in Lithuania has started only recently, and thus, the development of this production is in its initial stage. According to the data from the Lithuanian website for renewable energy sources, currently, of the 40 biogas plants operating in Lithuania, only 10 have been installed on livestock farms (more specifically on large-scale pig farms) and use animal manure (pig manure) as a feedstock for biogas production. The total installed capacity of these plants amounts to 9.4 MW_{el} [15]. Since there has been limited adoption of biogas technology on farms, therefore it is of particular interest to evaluate development opportunities for biogas production from animal manure in Lithuania.

MATERIALS AND METHODS

This study consists of two parts. The first part of the study aimed to estimate the total amount of animal manure (liquid and solid) generated in Lithuania over the last year and to define the counties with the highest concentration of animal manure production, whereas the second part aimed to investigate the views and opinions on biogas production from animal manure of Lithuanian large-scale livestock farmers and representatives of agricultural holdings.

The equation in estimating the total amount of animal manure (liquid and solid) generated in the country for a given year was used as follows:

$$M = \sum_T \left((MC_{T(S)} \times N_T + MC_{T(L)} \times N_T) \times 12 \times 0.7 \right);$$

in this equation:

M – total amount of animal manure (liquid and solid) generated in the country for a given year, tonnes;

$MC_{T(S)}$ – extraction coefficient of solid manure for animal type T, m^3 $head^{-1}$ $month^{-1}$;

$MC_{T(L)}$ – extraction coefficient of liquid manure for animal type T, m^3 $head^{-1}$ $month^{-1}$;

N_T – animal population of animal type T (number of heads);

T – animal type;
12 – months year^{-1};
0.7 – conversion coefficient of m^3 to tonnes.
The total amount of animal manure was calculated as the sum of liquid and solid manure generated by all animal types. The extraction coefficients of solid and liquid manure for different animal types were taken from the 'Advanced farming rules and recommendations' and the animal population (number of heads) was obtained from Statistics Lithuania [1; 20].
In order to investigate the views and opinions on biogas production from animal manure of Lithuanian large-scale livestock farmers and representatives of agricultural holdings, the survey method was employed. The survey was addressed to the large-scale livestock farmers and representatives of agricultural holdings having a herd size of about 500 or more head of cattle and of 1,000 or more head of pigs. The information was obtained by means of a standardised questionnaire which was sent to 95 respondents identified as the potential biogas plant operators. The survey took place in February 2018. A total of 25 large-scale livestock farmers and representatives of agricultural holdings filled the questionnaire: 19 of respondents had a herd size of more than 500 head of cattle, 3 of which reared cattle and other animals (1 respondent reared cattle and more than 1,000 head of pigs, 1 respondent reared cattle and less than 1,000 head of pigs, and 1 respondent reared cattle and poultry), 2 respondents had a herd size of less than 500 head of cattle and 4 respondents had a herd size of more than 1,000 head of pigs.
The questionnaire included questions on: connection with activities related to biogas production from animal manure; level of awareness of biogas technology and economy, and support schemes for biogas; intention to produce biogas from animal manure on farms in the future; motives and obstacles for installing biogas system on farms; awareness of the interest of local rural communities in the construction of biogas plants. Data were also collected on general farm characteristics – herd size and structure of the herd.
Descriptive statistics of frequency, mean and standard deviation were applied to examine the data from the survey.

RESULTS AND DISCUSSIONS

Animal manure production for Lithuania
In 2017, the total amount of animal manure in Lithuania was estimated to be 16,223 thousand m^3 or 11,356 thousand tonnes. Cattle manure accounted for the highest share of the total amount of animal manure generated in the country (76%). The remaining manure was from poultry (12%), pigs (8%), and sheep, goats and horses, taken together (4%). In terms of geographical distribution, the county that generated the most animal manure was Šiauliai (2,101 thousand m^3 or 1,471 thousand tonnes), followed by Kaunas (2,069 thousand m^3 or 1,448 thousand tonnes), and Tauragė (1,972 thousand m^3 or 1380 thousand tonnes) (Table 1).

Table 1. Total amount of animal manure generated in Lithuania in 2017 by county and animal type, thousand m^3

County	Total amount of animal manure generated in Lithuania, thousand m^3				
	Cattle	Pigs	Poultry	Sheep, goats and horses	**Total**
Alytus	632	19	44	76	**771**
Kaunas	1,542	175	267	85	**2,069**
Klaipėda	1,444	99	96	41	**1,679**
Marijampolė	1,324	105	47	38	**1,514**
Panevėžys	1,442	221	175	46	**1,884**
Šiauliai	1,648	268	117	67	**2,101**
Tauragė	1,795	115	29	33	**1,972**
Telšiai	1,216	50	300	43	**1,608**
Utena	756	87	89	122	**1,054**
Vilnius	561	86	813	113	**1,573**
Total, thousand m^3	**12,360**	**1224**	**1977**	**663**	**16,223**
Share, % of total in Lithuania	**76**	**8**	**12**	**4**	**100**

Note: 1 m^3 = 0.7 tonne.
Source: Own calculations.

The largest amounts of animal manure were generated in the counties where large-scale livestock farms prevailed. In 2017, there were 93 cattle farms with 500 or more head of cattle and 53 pig farms with 1,000 or more head of pigs (Table 2).

Table 2. Large-scale cattle and pig farms, and biogas plants in Lithuania in 2017 by county

County	Cattle farms with 500 or more head of cattle			Pig farms with 1000 or more head of pigs			Number of agricultural biogas plants
	Number of farms	Number of cattle (heads)	Average number of cattle (heads)	Number of farms	Number of pigs (heads)	Average number of pigs (heads)	
Alytus	1	585	585	1	1,014	1,014	–
Kaunas	15	19,622	1,308	11	84,585	7,690	–
Klaipėda	4	2,776	694	4	38,076	9,519	–
Marijampolė	17	22,011	1,295	4	35,486	8,872	1
Panevėžys	20	23,767	1,188	6	100,812	16,802	2
Šiauliai	26	30,663	1,179	12	131,649	10,971	4
Tauragė	5	3,457	691	3	37,527	12,509	–
Telšiai	1	901	901	3	21,132	7,044	–
Utena	2	1,672	836	6	44,337	7,390	2
Vilnius	2	1,869	935	3	34,232	11,411	1
Lithuania	**93**	**107,323**	**1,154**	**53**	**528,850**	**9,978**	**10**

Source: Own calculations.

In 2017, the average number of cattle on large-scale cattle farms was 1,154 and the average number of pigs on large-scale pig farms was 9,978. Large-scale cattle farms in Kaunas, Marijampolė, Panevėžys and Šiauliai counties were bigger than the average large-scale cattle farm for the country. The biggest large-scale pig farms were in Panevėžys, Tauragė, Vilnius and Šiauliai counties. The counties with the highest numbers of large-scale livestock farms (mainly the northern and central parts of Lithuania) were identified as the potential areas where biogas plants could be built. In 2017, approximately 1,913 thousand m^3 or 1,339 thousand tonnes of cattle manure was generated from large-scale cattle farms, which accounted for 15% of the total amount of cattle manure generated in Lithuania, and approximately 972 thousand m^3 or 680 thousand tonnes of pig manure was generated from large-scale pig farms, which accounted for 79% of the total amount of pig manure generated in Lithuania (the total amount of animal manure generated from large-scale livestock farms was estimated using an average amount of manure generated per animal per year and the total number of animals on large-scale livestock farms) (Table 3).

Of all large-scale livestock farms, only 10 pig farms have adopted biogas technology (Table 2). These biogas plants utilize only a very small share of the total amount of animal manure generated in Lithuania. No any biogas project has been developed on large-scale cattle farms. Given the facts that large-scale livestock farms produce significant amounts of animal manure and face the most serious problems related to animal manure management, it is appropriate to construct biogas plants on these farms in particular. At present, there are 136 large-scale livestock farms in Lithuania, where biogas systems are feasible.

Table 3. Total amount of animal manure generated from large-scale cattle and pig farms in Lithuania in 2017 by county, thousand m^3

County	Average amount of manure generated per animal per year, m^3		Total amount of animal manure generated from large-scale livestock farms in Lithuania, thousand m^3	
	Cattle	Pig	Cattle farms with 500 or more head of cattle	Pig farms with 1000 or more head of pigs
Alytus	18.01	2.09	11	2
Kaunas	17.59	1.81	345	153
Klaipėda	17.40	1.83	48	70
Marijampolė	18.12	1.95	399	69
Panevėžys	18.20	1.86	433	187
Šiauliai	17.49	1.82	536	240
Tauragė	18.20	1.87	63	70
Telšiai	17.60	1.77	16	37
Utena	17.65	1.87	30	83
Vilnius	17.49	1.76	33	60
Total, thousand m^3	–	–	**1,913**	**972**

Source: Own calculations.

The results of the research conducted by the European Commission's Joint research centre revealed that the total amount of animal manure in Lithuania was estimated to be about 10.7 million tonnes fresh matter per year (data on animal population represented the average values for the period 2009–2013). Of the total amount of animal manure, only 5.3 million tonnes could be collected.

Between 157 and 212 biogas plants, with a total installed capacity between 29.1 MW_{el} and 35.2 MW_{el}, and an average capacity between 137 kWe and 224 kWe, could be built in Lithuania in the two scenarios analysed: variable collection area and a constant (10 km) collection radius, respectively [19].

Survey results

Lithuanian large-scale livestock farmers and representatives of agricultural holdings identified as the potential biogas plant operators were interviewed. First of all, respondents were asked about their connection with activities related to biogas production from animal manure. Some types of this connection were distinguished. The majority of interviewees (44%) stated that they are considering whether it is worthwhile to invest in installing biogas system on their farms. Almost one fifth of survey participants (19%) pointed out that they are already planning to construct biogas plants on their farms. However, slightly more than one quarter of respondents (26%) claimed that they are not, in principle, interested in installing biogas system on their farms (Table 4).

Table 4. Respondents' connection with activities related to biogas production from animal manure

Statements	Answers	
	Number	%
Respondent is considering whether it is worthwhile to invest in installing biogas system	12	44%
Respondent is not, in principle, interested in installing biogas system on farm	7	26%
Respondent is planning to construct a biogas plant	5	19%
Biogas plant is already operating on the farm	1	4%
Respondent supplies animal manure to a biogas plant	0	0%
Other	2	7%

Source: Own calculation from Field survey.

In this question, an *'Other'* category was included and this allowed interviewees to indicate issues that had not been included in the list. One survey participant reported that the economic evaluation carried out 5 years ago confirmed that the construction of a biogas plant on the farm would be not cost effective. Another respondent noted that she/he is hesitant about installing biogas system on the farm.

Respondents were asked if they are being aware of biogas production from animal manure, using a 5-point rating scale (1 – 'Not at all aware', 5 – 'Extremely aware'). It was found that the level of awareness of biogas technology and economy, and support schemes for biogas was low. 60% of interviewees (those who chose '1' or '2' on the scale) indicated non-awareness of support schemes for biogas, with mean score 2.2 (SD = 1.0). An equal percentage of survey participants, 48% each, stated being not at all aware or slightly aware of biogas technology and economy (Table 5).

Table 5. Respondents' awareness of biogas production from animal manure

Area of awareness	Results, %			Mean	SD
	Awareness[1]	Somewhat awareness[2]	Non-awareness[3]		
Technology	12%	40%	48%	2.5	1.0
Economy	16%	36%	48%	2.6	1.2
Support schemes	8%	32%	60%	2.2	1.0

In this table:
[1]Awareness – categories 'Extremely aware' and 'Moderately aware' were merged;
[2]Somewhat awareness – category 'Somewhat aware';
[3]Non-awareness – categories 'Not at all aware' and 'Slightly aware' were merged;
SD – Standard Deviation.
Source: Own calculation from Field survey.

Respondents were asked if they are going to construct biogas plants on their farms over the next 10 years, using a 5-point rating scale (1 – *'Definitely not going to construct'*, 5 – *'Definitely going to construct'*). 29% of survey participants noted that they are definitely or most probably going to construct biogas plants, and 46% of interviewees reported that they are definitely or most probably not going to construct biogas plants. The mean score of this item was 2.7 (SD = 1.3) (Table 6).

Respondents were asked if they are aware of the interest of local rural communities in the construction of biogas plants. The majority of interviewees (68%) reported that they have no information regarding this interest, and one

fifth of survey participants (20%) stated that local rural communities are interested in the construction of biogas plants (Table 7).

Table 6. Respondents' intention to construct biogas plants on their farms over the next 10 years

Results, %			Mean	SD
Intention[1]	Neutral[2]	No intention[3]		
29%	25%	46%	2.7	1.3

In this table:
[1]Intention – categories 'Definitely going to construct' and 'Most probably going to construct' were merged;
[2]Neutral – category 'Neutral';
[3]No intention – categories 'Definitely going to construct' and 'Most probably going construct' were merged.
Source: Own calculation from Field survey.

Table 7. Respondents' awareness of the interest of local rural communities in the construction of biogas plants

Statements	Respondents	
	Number	%
No information	17	68%
Yes, local rural community is interested	5	20%
No, local rural community is not interested	3	12%

Source: Own calculation from Field survey.

Respondents were provided with the list of motives and obstacles for installing biogas system on farms and then asked to assess the level of agreement towards each statement, using a 5-point rating scale (1 – *'Totally disagree'*, 5 – *'Totally agree'*).
Of the statements relating to obstacles for installing biogas system on farms, interviewees expressed the strongest agreement with the item suggesting that investment is needed to solve some other problems on their farms. The mean score of this items was 4.1 (SD = 0.9), with 76% of survey participants (those who chose '4' or '5' on the scale) indicating agreement. Other obstacles such as 'Low purchase for electricity', 'Concerns of drawing attention away from primary farm activity', 'Lack of financial capacity', 'Unfamiliar technology and lack of specialists' and 'Insufficient level of support and unattractive support conditions' also received strong endorsement, with mean scores ranging from 3.6 to 3.9, and agreement percentages ranging from 52% to 68% (Table 8).
Of the statements relating to motives for installing biogas system on farms, the items generating the strongest agreement were 'Possibility to produce the own energy (electricity and heat)' and 'Complaints by local residents about animal manure management (odour reduction)'. The mean scores of these items were 3.8 (SD = 0.9) and 4.0 (SD = 0.9), respectively, with an equal percentage of survey participants, 72% each (those who chose '4' or '5' on the scale), indicating agreement.

Table 8. Obstacles for installing biogas system on farms

Obstacles	Results, %			Mean	SD
	Agreement[1]	Neutral[2]	Disagreement[3]		
Competing investment priorities	76	20	4	4.1	0.9
Low purchase price for electricity	72	24	4	4.0	0.9
Concerns of drawing attention away from primary farm activity	68	16	16	3.8	1.1
Lack of financial capacity	68	20	12	3.9	1.0
Unfamiliar technology and lack of specialists	64	24	12	3.7	0.9
Insufficient level of support and unattractive support conditions	52	40	8	3.6	1.0
Low familiarity with the opportunity to construct a biogas plant	44	48	8	3.1	1.2
Uncertainty about maintaining the same number of animals	36	32	32	3.0	1.3
High price of animal manure	24	40	36	3.0	1.0
Hostility of local residents to biogas plants	24	48	28	3.0	1.0
Insufficient amount of animal manure and other agricultural residues	20	24	36	2.6	1.0
Limited possibilities to obtain a loan	16	40	44	2.7	1.1
Non-compliance to eligibility criteria for support	12	52	36	2.6	1.1
Lack of consultations	4	40	56	2.6	0.8
Problems related to the construction site selection	4	24	72	2.2	0.9

In this and following table:
[1] Agreement – categories 'Totally agree' and 'Agree' were merged;
[2]Neutral – category 'Neither agree nor disagree';
[3]Disagreement – categories 'Totally disagree' and 'Disagree' were merged.
Source: Own calculation from Field survey.

Table 9. Motives for installing biogas system on farms

Motives	Results, %			Mean	SD
	Agreement[1]	Neutral[2]	Disagreement[3]		
Possibility to produce the own energy (electricity and heat)	72	24	4	3.8	0.9
Complaints by local residents about animal manure management (odour reduction)	72	20	8	4.0	0.9
Higher tariffs for produced energy	68	24	8	3.9	1.0
Increased support for investment	64	20	16	3.6	1.1
Possibility to get electricity quota	53	35	12	3.5	1.2
Detailed information regarding the construction of a biogas plant and the possibilities of consulting farmers who have already adopted biogas technology	52	44	4	3.8	0.9

Source: Own calculation from Field survey.

Other motives such as, 'Higher tariffs for produced energy' and 'Increased support for investment' also received strong endorsement, with mean scores ranging from 3.6 to 4.0, and agreement percentages ranging from 64% to 72% (Table 9).

These results supported some previous studies conducted in other countries suggesting that, as regards installing biogas system on farms, the major obstacles were associated with financial issues [3; 21], whereas the main motive was related to the production of own energy [22].

In order to promote the development of biogas production from animal manure in Lithuania, significant efforts should be made to strengthen the incentives and weaken the barriers. Particular attention must be given to raising awareness of the benefits of biogas production from animal manure among potential biogas plant operators and setting out long-term and stable support policies for biogas.

CONCLUSIONS

In order to evaluate development opportunities for biogas production from animal manure in Lithuania, in this study, the total amount of animal manure generated in the country over the past year was estimated and the views and opinions on biogas production from animal manure of Lithuanian large-scale farmers and representatives of agricultural holdings were investigated by conducting a survey.

The total amount of animal manure in Lithuania was estimated to be 11.4 million tonnes in 2017. The counties that generated the most animal manure were Šiauliai, Kaunas and Tauragė. The highest numbers of large-scale livestock farms were mainly located in the northern and central parts of Lithuania (Šiauliai, Panevėžys, and Kaunas counties) and these parts were identified as the potential areas where biogas plants could be built.

Of all large-scale livestock farms, only 10 pig farms had adopted biogas technology. Although cattle manure accounted for the majority of the total amount of animal manure in Lithuania, no any biogas project had been developed on large-scale cattle farms. In that regard, particular efforts should be made in order to encourage large-scale livestock farms to invest in biogas plants.

The results of the survey revealed that the level of awareness of biogas technology and economy, and support schemes for biogas among the potential biogas plant operators was low. The possibility to produce the own energy (electricity and heat) and complaints by local residents about animal manure management (odour reduction) were identified as the main motives for installing biogas system on farms. The belief that investment is needed to solve some other problems on farms was found as the major obstacle for installing biogas system on farms.

The results of this study are important for Lithuanian farmers and agricultural holdings in raising awareness of the benefits of biogas production from animal manure and stimulating interest in adopting biogas technology on farms.

Also, the results of this study provide useful information for policy makers in establishing the policy framework and introducing support schemes that would promote the development of biogas production from animal manure in Lithuania.

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