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**Production and consumption aspects of biogas in cattle farming businesses of Ukraine**

**Summary.** Production and consumption aspects of biogas at farm enterprises of Ukraine were identified. Preconditions of negative changes in cattle farming were studied. The research done made it possible to evaluate production efficiency of both beef and alternative fuel – biogas – at farm enterprises. A polynomial model, which describes potential of biogas production in the years of 1990–2013 and envisages further increase of this indicator, was developed. It has been established that biogas production and consumption from cattle substrates at farm enterprises will allow producing ecologically clean alternative fuel, ensuring food safety, creating new jobs, increasing business profits, reducing import fuel dependence. The research results can help solve practical problems of farm enterprises in cattle farming and in agrarian business in general.

**Key words:** biogas, cattle, profitability level, production cost, price, efficiency, farm enterprises

**Problem definition**

Price increase of fuel, when paying capacity of the businesses in Ukraine's AIC is low, may have a negative impact on line balance. The solution of the mentioned problems becomes more urgent, and first of all by means of using alternative energy sources for farm production. Our country provides itself with own energy sources partially, and it has to import about 65% of excavated power carriers. In 2013 over 30 bln m<sup>3</sup> of natural gas was imported, and 93% came from Russian Federation<sup>1</sup>. Hence biogas production and consumption will decrease business dependence on traditional fuel import and ensure competitive power of the output of Ukraine's AIC.

The issues of production and consumption of alternative kinds of fuel are discussed in the works of: H.M. Kaletnik, M.Yu. Kodenska, V.Ya. Mesel-Veseliak, M.V. Royik, P.T. Sabluk, O.M. Shpychak, V.S. Bondar, Yu.V. Kernasiuk, A.V. Fursa, M.M. Yarchuk and others. However, the issue of biogas production at farm enterprises, in particular from cattle substrates, needs additional studying.

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<sup>1</sup> M.V. Royik: Power engineering in Ukraine: status and development trends, Bio-power Engineering 2013, nr 1, s. 5.

The purpose of the research is to evaluate the potential of biogas production and consumption from cattle substrates at farm enterprises of Ukraine, taking into account its effect on business economic efficiency.

### **Research methodology**

The following practices were used in the process of research: system analysis and logical generalization – to study preconditions of negative changes in cattle farming; economic-mathematic modeling – to work out a polynomial model which describes biogas production potential at cattle farm enterprises as to natural gas; settlement-constructive – to determine the indicators of economic efficiency in cattle farming; induction and deduction – to generalize the research results; abstract-logic – to make conclusions and suggestions.

### **Results of the research**

The main bio-energy products of the first processing cycle of cattle substrates are biogas and organic fertilizers, those of the second cycle – power energy and heat. With proper cleaning, biogas is raw material for getting highly-octane gas-like fuel which can substitute natural gas. From economic point of view, biogas is to be considered as the output of industrial processing of organic livestock wastes, which may bring additional income to a producer and enhance economic efficiency in cattle farming. This is particularly important in this branch as the problem of beef production loss is one of the reasons of its regress<sup>2</sup>.

Raw materials for biogas devices are agricultural substrates, such as liquid and stable manure and energy crops (sugar and fodder beets, corn, sugar sorghum, silver grass, etc.). Substrates, which are by-products of processing industry and organic utility wastes, are also used. The most promising agricultural crops, whose raw materials can be used to get biogas, are sugar sorghum (biogas yield – 17.6 th. m<sup>3</sup>/ha), corn for silage (16.0 th. m<sup>3</sup>/ha), sugar beets (10.9 th. m<sup>3</sup>/ha), and fodder beets (10.8 th. m<sup>3</sup>/ha)<sup>3</sup>. However, the use of corn with energy aim may cause the decrease of foodstuff and fodder. Taking into account the necessity to ensure national food security, it is expedient to use corn for silage for cattle fattening, which will make it possible to produce beef for population and biogas from manure – alternative fuel.

In the years of 2000–2014 we see a noticeable increase of industrial crop share in the total sown area of agricultural crops, namely, sunflower – 10.8% in 2000 to 19.3% in 2014, soybeans – 0.2% in 2000 to 6.6% in 2014, rape – 0.8% in 200 to 3.2% in 2014. At

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<sup>2</sup> Yu.V. Kernasiuk: Scientific-methodological approaches to the determination of production cost and economic efficiency of bio-energy output of manure utilization, Proceedings of Kirovohrad National Technical University, Economic Sciences 2010, s. 165.

<sup>3</sup> M.V. Royik: The concept of biogas production from bio-energy crops in Ukraine, Bio Power Engineering 2014, nr 2, s. 6.

the same time sown areas of corn for silage decreased – 7.1% in 2000 to 1.3% in 2014 which affected the development of livestock production in Ukraine<sup>4</sup>.

Following the elements of farm practices of agricultural crops, the main ones are the introduction of new high-yielding varieties and hybrids, top dressing of crops and pest management (pests, diseases and weeds) along with soil-climatic conditions of Ukraine, ensured the yield increase of the crops in this period: corn for silage by 66.5% – to 21.85 t/ha in 2014, sunflower by 59.0% – to 1.94 t/ha in 2014, soybeans by 103.8% – to 2.16 t/ha in 2014, rape by 202.4% – to 2.54 t/ha in 2014. However, the potential of these crops is still high in Ukraine.

Thus, in the years of 2000–2014 production enhancement of these crops is recorded both at the expense of their share increase in the total sown area and their yield increase (Table 1).

**Table 1.** Production indicators of some farm crops in Ukraine in 2000–2014 (farms of all categories)

Indicators	Year					2014 in % to	
	2000	2011	2012	2013	2014	2000	2013
<b>Corn for silage, haylage, green fodder</b>							
Share of the total sown area (%)	7.1	1.6	1.8	1.4	1.3	–	–
Output volume (th. t)	24,183.3	9,993.5	8,268.4	8,454.3	7,573.5	31.3	89.6
Yield (t/ha)	13.12	22.53	16.75	21.56	21.85	166.5	101.3
<b>Sunflower</b>							
Share of the total sown area (%)	10.8	17.1	18.7	18.0	19.3	–	–
Output volume (th. t)	3,457.4	8,670.5	8,387.1	10,941	10,133.8	293.1	92.6
Yield (t/ha)	1.22	1.84	1.65	2.19	1.94	159.0	88.6
<b>Soybeans</b>							
Share of the total sown area (%)	0.2	4.1	5.3	4.9	6.6	–	–
Output volume (th. t)	64.4	2,264.4	2,410.2	2,740.7	3,881.9	6,027.8	141.6
Yield (t/ha)	1.06	2.04	1.71	2.05	2.16	203.8	105.4
<b>Rape (winter and spring)</b>							
Share of the total sown area (%)	0.8	3.1	2.0	3.7	3.2	–	–
Output volume (th. t)	131.8	1,437.4	1,204.4	2,335.3	2,198	1,667.7	94.1
Yield (t/ha)	0.84	1.73	2.2	2.36	2.54	302.4	107.6

Source: data of the State statistics committee of Ukraine<sup>5</sup>; 2013 and 2014 – excluding temporarily occupied Autonomous Republic of the Crimea and city of Sevastopol, part of the ATO area

<sup>4</sup> Crop production of Ukraine: Statistical Bulletin of the year of 2014, State statistics committee of Ukraine, Kyiv 2015.

<sup>5</sup> Ibidem.

In particular, favorable foreign market condition and price increase, high rate of return of sunflower, soybeans and rape encourage farm producers to extend their sown areas as compared with those under other crops.

Thus, the rate of return of sunflower seeds increased from 18.4% in 2008 to 28.5% in 2013, soybeans – from 1.3% in 2008 to 15.8% in 2013, and the rate of return of rape decreased from 51.3% in 2008 to 8.6% in 2008. The decrease of the rate of return of rape in 2013 resulted in production cost increase of 1 t by 98.1%, but the average marketing price of 1 t increased only by 42.2%. Correspondingly, production cost of 1 t of sunflower increased by 97.7%, and the average marketing price of 1 t increased by 114.6%, production cost of 1 t of soybeans increased by 68.0%, and the average marketing price of 1 t increased by 92.1% (Table 2).

**Table 2.** Economic production efficiency of some farm crops in Ukraine in 2008–2013 (farm enterprises)

Indicator	Year						2013 in % to	
	2008	2009	2010	2011	2012	2013	2008	2012
<b>Sunflower seeds</b>								
Absorption costing of 1 t (UAH)	1,173.6	1,342	1,839	2,054	2,463	2,320.5	197.7	94.2
Average marketing price of 1 t (UAH)	1,389.5	1,898	3,028	3,225	3,591	2,982.1	214.6	83.0
Rate of return (%)	18.4	41.4	64.7	57.0	45.8	28.5	–	–
<b>Soybeans</b>								
Absorption costing of 1 t (UAH)	1,764.1	2,033	2,238	2,352	2,784	2,964.0	168.0	106.5
Average marketing price of 1 t (UAH)	1,786.6	2,725	2,605	2,918	3,435	3,432.2	192.1	99.9
Rate of return (%)	1.3	34.1	16.4	24.1	23.4	15.8	–	–
<b>Rape</b>								
Absorption costing of 1 t (UAH)	1,429.8	1,911	2,315	3,151	3,233	2,832.6	198.1	87.6
Average marketing price of 1 t (UAH)	2,163.4	2,366	2,931	4,162	3,923	3,077.0	142.2	78.4
Rate of return (%)	51.3	23.8	26.6	32.1	21.4	8.6	–	–

Source: calculation according to the data of the State statistics committee of Ukraine<sup>6</sup>.

It has to be noted that in Ukraine grain crop export increases and meat and by-products take the largest import share with the EU; this tendency may have a negative effect on the development of domestic livestock production.

<sup>6</sup> Basic economic indicators of agricultural production at agricultural enterprises: Statistics Bulletin of the year of 2008, 2009, 2010, 2011, 2012, 2013, State statistics committee of Ukraine, Kyiv 2009, 2010, 2011, 2012, 2013, 2014.

In Ukraine meat consumption of all kinds per capita in 2014 was 56.1 kg – it increased by 71%, compared with the year of 2000, respectively, meat production – 52.5 kg or 55.3% increase. It explains the need to increase meat production by 34% to reach rational annual consumption rate – 85 kg per year. It should be done by beef and veal production. Since cattle stock decreased by 51.9% – to 4,534 th. head in 2000–2013, cattle raising decreased by 38.2%, beef and veal share in the total meat production structure decreased from 45.3% in 2000 to 17.9% in 2013<sup>7</sup> (Table 3).

**Table 3.** Indicators of meat production and consumption in Ukraine in 2000–2013 (farms of all categories)

Indicators	Year					2013 in % to	
	2000	2010	2011	2012	2013	2000	2012
Meat production of all kinds (slaughter weight) (kg per 1 person)	33.8	44.9	46.9	48.5	52.5	155.3	108.2
Meat consumption of all kinds (kg per 1 person)	32.8	52.0	51.2	54.4	56.1	171.0	103.1
Cattle stock (th. head)	9 423.7	4 494	4 426	4 646	4 534	48.1	97.6
Cattle raising (live weight) (th. t)	1 090.1	653.8	640.7	671.1	674.2	61.8	100.5
Production (slaughter weight):							
Beef and veal (th. t)	754.3	427.7	399.1	388.5	427.8	56.7	110.1
In % to meat of all kinds	45.3	20.8	18.6	17.6	17.9	–	–

Source: calculation according to the data of the State statistics committee of Ukraine<sup>8</sup>.

The analysis of meat production efficiency in Ukraine has proved the loss of beef production in recent years which led to the cattle stock reduction. Loss ratio of cattle marketing was 24.1% in 2008, respectively – 43.3% in 2013<sup>9</sup>. So, farm producers do not consider beef production to be attractive.

In the period of 2008–2013 the volume of marketed output of farm enterprises decreased by 15% – to 188.8 th. t, a price taking an important place in beef market regulation. During this period an average marketing price of 1 t of meat increased by 26.1% – to 10,537 UAH/t in 2013, correspondingly, production cost – by 68.7% – to 18,575.8 UAH/t. The fact that marketing meat prices do not cover the production expenses led to the losses of the majority of farm enterprises in cattle farming, and in turn, to the reduction of cattle stock (Table 4).

<sup>7</sup> Agriculture of Ukraine: Statistics Bulletin of the year of 2013, State statistics committee of Ukraine, Kyiv 2014.

<sup>8</sup> Ibidem.

<sup>9</sup> Basic economic..., op.cit.

**Table 4.** Economic efficiency of marketing cattle to produce meat in Ukraine in 2008–2013 (farm enterprises)

Indicator	Year						2013 in % to	
	2008	2009	2010	2011	2012	2013	2008	2012
Volume of marketed output (th. t)	222.1	200.6	191.9	170.7	166.7	188.8	85.0	113.3
Absorption costing 1 t (UAH)	11,013.6	12,369	13,972	15,909	17,549	18,575.8	168.7	105.9
Average marketing price 1 t (UAH)	8,355.3	8,306	8,961	11,967	12,369	10,537	126.1	85.2
Rate of return (loss ratio) (%)	-24.1	-32.9	-35.9	-24.8	-29.5	-43.3	-	-

Source: calculation according to the data of the State statistics committee of Ukraine<sup>10</sup>.

To calculate meat production of cattle and biogas from manure, we take average yield of corn for silage at various levels of soil water supply: 40 t/ha – a zone of insufficient ground moistening, 50 t/ha – unstable moistening, 60 t/ha – sufficient moistening. In Ukraine south-east areas of Cherkasy, Kharkiv and Poltava regions, northern areas of Kirovohrad region belong to a zone of insufficient moistening. A zone of unstable moistening covers southern areas of Khmelnytsk, Vinnytsia, Kyiv and Sumy regions, northern areas of Cherkasy, Poltava and Kharkiv regions. Ivano-Frankivks, Lviv, Chernivtsi, Ternopil, Chernihiv, Khmelnytsk, Zhytomyr regions and northern part of Vinnytsia region belong to the agro-climatic zone of sufficient moistening.

Fattening of cattle is done on pastures or in stalls. Cheap fodder is used in stable feeding. They are by-products of food industry – press-cake, grain, molasses or succulent fodder of in-farm production – silage, haylage, melons, grass, fodder-mixtures in semi-moist or granular condition.

Depending on the yield of corn for silage meat production indicators per 1 hectare will differ: 1,320 kg when corn yield for silage is 40 t/ha, respectively – 1,650 kg – 50 t/ha, 1,980 kg – 60 t/ha (Table 5).

According to the National statistics department of Ukraine in February, 2015 average marketing price of 1 t of cattle (live weight) was UAH 20,000 or 20 hrivni per 1 kg<sup>11</sup>. Under such conditions income from meat sale of cattle is 13,992 UAH/ha when yield of corn for silage is 40 t/ha, respectively 17,490 UAH/ha – to 50 t/ha, 20,988 UAH/ha – 60 t/ha. Rate of return of meat production is 113%.

<sup>10</sup> Basic economic..., op.cit.

<sup>11</sup> State of agriculture in January-February, 2015 [electronic resource], Access mode: <http://www.ukrstat.gov.ua>.

**Table 5.** Production efficiency of cattle meat and biogas from substrates at farm enterprises (as of March 1, 2015)

Indicators	Yield of corn for silage (t/ha)		
	40	50	60
Produced amount of meat of cattle per 1 ha (kg)	1,320	1,650	1,980
Meat production cost (UAH/ha)	12,408	15,510	18,612
Meat sales revenue (UAH/ha)	26,400	33,000	39,600
Income from meat sale (UAH/ha)	13,992	17,490	20,988
Production cost of 1 kg of meat (UAH)	9.4		
Marketing price of 1 kg of meat (UAH)	20		
Income from sale of 1 kg of meat (UAH)	10.6		
Rate of return of meat production (%)	113		
Biogas amount per 1 ha (m <sup>3</sup> )	4,015	5,019	6,023
Biogas production cost (UAH/ha)	11,644	14,555	17,467
Biogas amount in terms of methane per 1 ha (m <sup>3</sup> )	2,208	2,760	3,313
Biogas sales revenue per 1 ha (UAH)	19,651	24,564	29,486
Income from biogas sale (UAH/ha)	8,007	10,009	12,019
Biogas production cost in terms of methane 1 m <sup>3</sup> (UAH)	5.3		
Biogas price in terms of methane 1 m <sup>3</sup> (UAH)	8.9		
Income from sale 1 m <sup>3</sup> (UAH)	3.6		
Rate of return of biogas production (%)	68		

Source: our calculations.

In compliance with departmental standards of technological design ВНТП–АПК–09.06 “Systems of extraction, processing, preparation and use of manure”<sup>12</sup> biogas is a combustible gas, which consists of 55–70% of methane and 30–45% of carbon dioxide, which is why the amount of biogas in terms of methane is 2,208 m<sup>3</sup> per 1 ha, when yield of corn for silage is 40 t/ha, correspondingly 2,760 m<sup>3</sup> per 1 ha when yield of corn for silage is 50 t/ha, 3,313 m<sup>3</sup> per 1 ha when yield of corn for silage is 60 t/ha.

In addition, by the decision of the National board which exercises public regulation in the spheres of power engineering and municipal services № 227 of February 26, 2015, price ceiling of natural gas for industrial consumers and other business entities was fixed from March 1, 2015 – UAH 8,900 per 1,000 m<sup>3</sup><sup>13</sup>. Under such conditions, income from biogas sale is 8,007 UAH/ha when yield of corn for silage is 40 t/ha, re-

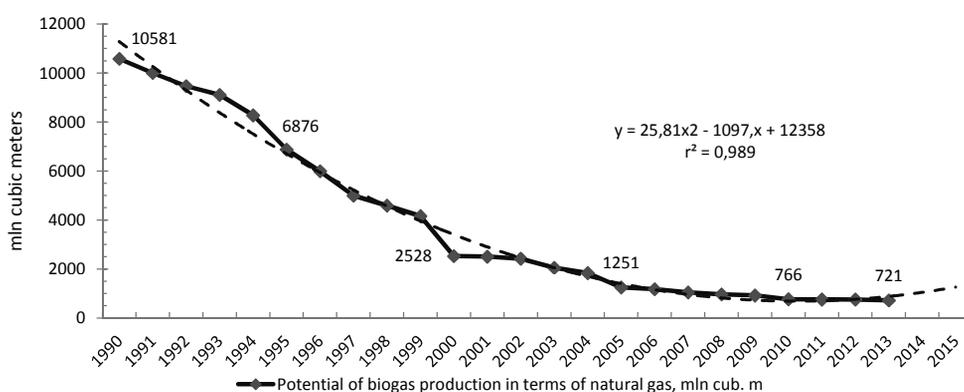
<sup>12</sup> System of extraction, processing, preparation and use of manure, Departmental standards of technological design of ВНТП–АПК–09.06, Ministry of agrarian policy of Ukraine, Kyiv 2006.

<sup>13</sup> Decision of the National board which exercises public regulation in the spheres of power engineering and communal services “The establishment of price ceiling of natural gas for industrial consumers and other business entities” of February 26, 2015, No. 227 [electronic resource], Access mode: <http://www.nerc.gov.ua/?id=14113>.

spectively 10,009 UAH/ha – 50 t/ha, 12,019 UAH/ha – 60 t/ha. Rate of return of biogas production is 69%.

Thus, biogas production from cattle substrates at farm enterprises will guarantee not only efficient meat production but also sources of renewable energy, which can reduce producers' dependence on expensive energy carriers, and in turn will facilitate the rebirth of cattle farming in Ukraine.

In spite of the cattle stock decrease at farm enterprises in 1990–2013, the potential of biogas production from cattle substrates can reach up to 10 billion cubic meters in terms of natural gas which constitutes 20% of natural gas consumption in Ukraine in 2013<sup>14</sup> (Figure 1).



**Figure 1.** Potential of biogas production at farm enterprises in cattle farming of Ukraine in terms of natural gas in various years

Source: our calculations.

According to the statistics of 2013, the potential of biogas production from cattle substrates in terms of natural gas is 721 mln cubic meters, which in terms of standard fuel is 830 th. t. Provided average price of 1,000 cubic meters of natural gas is UAH 8,900, the industry will get additional UAH 6.4 billion.

Hence, due to biogas production from cattle substrates farm enterprises will be able to replace 830 th. t of standard fuel, i.e., 43.7% of the total consumption in agriculture.

And first of all a considerable amount of biogas will be used to satisfy the needs of farm enterprises, however, provided proper equipment is used, the rest of the energy can be marketed to other consumers. It is possible to use devices for simultaneous production of energy and heat, and special equipment – to clean biogas and use it as ordinary fuel for vehicles and other farm machinery.

<sup>14</sup> Statistics Annual Book of Ukraine of the year of 2013, O.H. Osaulenko (red.), State statistics committee of Ukraine, Kyiv 2014.

It is expedient to use bio-energy clusters for biogas production, where cattle density is high and large cattle farms with over 500 head function<sup>15</sup>. These clusters should incorporate powerful biogas energy complexes, power stations on cogeneration devices and biogas refineries to produce gas-like fuel and to fuel transport means.

### Conclusions

Biogas production from cattle substrates at farm enterprises solves several problems of agrarian production. Firstly, it refers to the reduction of environmental pollution with dangerous substances, including liquid and solid wastes of cattle farms, and the limitation of methane emission into the atmosphere. Secondly, it creates new possibilities for farm enterprises in cattle farming to get additional profits which will enhance production efficiency of livestock output, in particular, loss decrease in beef production. Thirdly, it ensures food and energy security of the country due to the increase of beef production and the decrease of farm producers' dependence on import fuel. Also, social problems in rural area are solved by creating new and saving existing jobs. Thus, to meet the needs of farm producers with bio-fuel at a lower price will favor competitive power of the production of agricultural output, and will also enhance business efficiency of the farm enterprises producing alternative energy sources.

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<sup>15</sup> Yu.V. Kernasiuk, The evaluation of biogas energy potential of cattle farming at farm enterprises, *AgroInCom* 2010, nr 4–6, s. 47.

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