German–Ukrainian Policy Dialogue in Agriculture
Institute for Economic Research and Policy Consulting

Policy Paper Series [AgPP No. 26]

Biogas and "green tariffs" in Ukraine – A profitable investment?

Anna Kuznetsova
Kateryna Kutsenko

Kyiv, January 2010

Acknowledgement

We highly appreciate the inputs and support, and express our sincere gratitude to everyone who participated in execution of this paper. In particular, we would like to thank:

Mr. Kovalenko Valeriy, the Head of Laboratory for ecological and sanitarian hygienic monitoring of agricultural enterprises of National Agrarian University of Ukraine, for giving the methodology to calculate biogas potential in Ukraine;

Ms. Ovcharenko Liliya, Ms. Masyuk Svitlana and other staff members of State Statistics Committee of Ukraine for granting data for our calculations;

Mr. Datsenko Mykola, Mr. Khomenko Yuriy and other staff members of the Ministry of Agrarian Policy of Ukraine for their valuable comments and advises;

ZORG Company for materials on equipment for biogas production.

About the Institute for Economic Research and Policy Consulting

The Institute for Economic Research and Policy Consulting (IER) is the leading Ukrainian analytical think tank focusing on economic research and policy advice. The IER was founded in October 1999 by top-ranking Ukrainian politicians and the German Advisory Group on Economic Reforms.

The mission of IER is to present an alternative point of view on key problems of social and economic development of Ukraine. In frame of the mission IER aims at providing top quality expertise in the field of economy and economic policy-making; acting as real leader of public opinion through organisation of open public dialog; contributing to the development of economic and political sciences as well as promoting development of Ukrainian research community.

Institute for Economic Research and Policy Consulting
Reytarska 8/5-A,
01034 Kyiv, Ukraine
Tel: +38 044 / 278 63 42
Fax: +38 044 / 278 63 36
institute@ier.kiev.ua
http://www.ier.kiev.ua

About the Project "German-Ukrainian Policy Dialogue in Agriculture"

The German-Ukrainian Policy Dialogue in Agriculture is advising Ukrainian state authorities and business associations on reforming agricultural policy and legislation, taking into account international experience of Germany and other countries as well as international practice (EU, WTO), in accordance with principles of market economy. The project is funded by the German Federal Ministry of Food, Agriculture and Consumer Protection under its Cooperation Program and by the German Centre for International Migration.

German-Ukrainian Policy Dialogue in Agriculture
Reytarska 8/5-A,
01034 Kyiv, Ukraine
Tel: +38 044 / 235 75 02
Fax: +38 044 / 278 63 36
agro@ier.kiev.ua
http://www.ier.kiev.ua

List of Recent Publications

- Agriculture, Bioenergy and Food Policy in Ukraine – Analyses, Conclusions and Recommendations. Editors: Heinz Strubenhoff, Igor Burakovsky and Veronika Movchan, Book, March 2009.

- Social Protection of the Population by Regulation of Food Prices and Trade Margins – Does the Law No. 1447-VI achieve its intended objectives? by Justyna Jaroszewska and Heinz Strubenhoff, Policy Paper AgPP28, November 2009

- Financial Crisis and Ukrainian Agriculture: Impact and Response, by Serhiy Kandul, Policy Paper AgPP27, November 2009

- Exporting electricity to the EU – more than switching frequencies, by Georg Zachmann, Dmytro Naumenko, Policy Paper PP/07/2009, November 2009

- The gas challenge, by Ferdinand Pavel, Dmytro Naumenko, Policy Paper PP/04/2009, July 2009

- How to develop a public debt market for retail investors?, by Ricardo Giucci, Robert Kirchner, Cyrus de la Rubia, Policy Paper PP/02/2009, July 2009

- Options for Ukraine with regard to its National Policy towards GMOs: the EU or US Model?, by Justyna Jaroszewska, Policy Paper AgPP25, June 2009

- The Role of Trade Policy in Reducing Ukraine's Current Account Deficit - Lessons from Abroad, by Christian Helmers, Veronika Movchan, Ricardo Giucci and Kateryna Kutsenko, Policy Paper PP/01/2009, March 2009

- European Markets for Meat: Real Opportunities for Ukraine?, by Sebastian Hess, Bernhard Voget and Anna Kuznetsova, Policy Paper AgPP24, Februrary 2009

- The Determinants of Dairy Farming Competitiveness in Ukraine, by Oleg Nivievskyi and Stephan von Cramon-Taubadel, Policy Paper AgPP23, September 2008

- The EU Dairy Market – Real Opportunities for Ukraine?, by Sebastian Hess, Bernhard Voget and Mariya Ryzhkova, Policy Paper AgPP19, September 2008

All papers and the book can be downloaded free of charge under http://www.ier.com.ua/ua/arhives_papers.php. For more information on subscription to our regular email-distribution, please contact Ms Iryna Slavinska by email: slavinska@ier.kiev.ua.

Executive summary

- The Ukrainian government encourages investments into the establishment of bioenergy facilities offering privileges for producers. Among these privileges is a higher tariff for electricity generated from alternative sources of energy – the so called "green tariff".
- The "green tariff" is a feed-in tariff differentiated for 1) each company that produces electricity from alternative sources of energy, 2) each type of alternative energy and 3) each single facility. The green tariff for electric energy from biomass is 1.6135 UAH/kWt including VAT. The difference between the "green" tariff and retail energy tariff gives biogas producers an opportunity to realize higher earnings than other energy producers.
- Ukraine has a biogas feedstock potential, that under current market conditions could allow to substitute 4-7% of annually produced electricity in Ukraine. The calculation of biogas potential from animal waste is done by using the conservative methodology of volatile substance, which takes into account dry manure. Numbers based on fresh manure amounts slightly differ from the results obtained by this methodology. In the case of corn silage the evaluation of the potential was based on the assumption that we substitute the total amount of corn export of the country with biogas production.
- To assess the profitability of biogas production in Ukraine we are differentiating between three feedstocks (pig and cattle manure, chicken dung and corn silage) and three scales of plants (installed electrical capacities of 0.5, 1 and 3 MWel).
- For the analysis of costs and benefits of biogas production we divide costs[1] into 2 groups: 1) production (purchase of equipment and construction land; personnel, electricity and water consumption), 2) operation and maintenance costs (costs to regularly provide biogas plant with raw materials and annual maintenance and repair costs of this equipment). The benefits can be obtained from the sale of electricity (produced from biogas and sold by green tariff) and from the sales or own use of bio fertilizers. After estimations of costs and benefits, we calculate the internal rates of return (IRR), payback periods (PP) and net present values (NPV). These indicators show the level of profitability of the biogas plants.
- The results show that biogas plants operating on pig and cattle manure are the most attractive for investors by all the plant scales. Biogas plants working on chicken dung and corn silage are profitable only if their capacity is 1 MWel and above.
- If the government fulfills its obligations to finance the "green tariff", thus ensuring investors stable framework conditions and levying the administrative functions of the involved state authorities, biogas production in Ukraine would be profitable. However, due to current state budget constraints it is likely that the growth rate of biogas production in Ukraine may be lower than in other European countries with feed-in "green tariffs".

Authors: Anna V. Kuznetsova kuznetsova@ier.kiev.ua +38 044 235 75 02
+38 095 410 401 9
Kateryna I. Kutsenko kutsenko@ier.kiev.ua +38 044 278 63 60

Lector: Dr. Heinz-Wilhelm Strubenhoff strubenhoff@ier.kiev.ua +38 044 278 63 60

[1] We include only those costs that are equal for all producers, excluding additional administrative and transaction costs, that might be case specific.

Table of contents

GLOSSARY

Biogas – a gas produced by the biological breakdown of organic matter in the absence of oxygen. Biogas originates from biogenic material and is a type of biofuel.

Volatile Substance (VS) - Volatile organic compounds (VOCs) are organic chemical compounds that have high enough vapor pressures under normal conditions to significantly vaporize and enter the atmosphere. VS = DM - (1 - ASH), where VS is volatile substances (kg per head for 24 h), DM is dry manure (kg per head for 24 h), ASH is share of ashes in manure (coefficient).

Net present value (NPV) - is the total present value (PV) of a time series of cash flows. NPV is an indicator of how much value an investment or project adds to the firm.

Internal rate of return (IRR) - is the annualized effective compounded return rate that can be earned on the invested capital.

Payback period (PP) - period of time required for the return on an investment to "repay" the sum of the original investment.

Cogeneration - is the use of a heat engine or a power station to simultaneously generate both electricity and useful heat

Green tariff - special differentiated tariff for electricity generated at the power plants that use alternative sources of energy.

National commission for electricity regulation of Ukraine (NERC) - state authority, empovered to control the working out and implementation of state policy for development and existence of the wholesale energy market as well as markets for gas, oil, and oil products.

MWel – installed electrical capacity of the plant, Mega Watt.

1. INTRODUCTION

Energy from renewable resources is a hot topic in Europe and all over the world today. Whereas bioethnol and biodiesel production cause more debate and the cost of the technologies is high, the boost of the number of biogas plants in the EU in the last five years is impressing. For example in Germany from 2000 to 2009 the number of biogas plants increased by more than 6 times and almost reached 5000 with the overall installed electrical capacity of 1600 MWel.[2] Biogas production in the EU is multi-purposed – it can be used as a substitution for natural gas, so as for heat and electricity generation. However, this rise of the production capacities was mostly conditioned by the legislative activity of the Governments, providing support to the producers of energy from renewable resources

The overall attention of the Ukrainian Government to the alternative sources of energy is mostly targeted at the increase of the energy security of the country and reduction of the imported natural sources of energy. Ukraine is in the very beginning of its way of introduction of renewable energy and until recently its legislative framework in the sector was general. Last year the Government introduced the legislative novel aiming to support production of energy from alternative resources - "green tariff" and offered producers of energy from alternative resources some more privileges such as tax exemptions and import duty exemptions for import of equipment. These government measures are expected to motivate investments and increase production of energy from biomass.

In this paper we assessed different opportunities for biogas production in Ukraine and its profitability under the newly introduced "green tariffs". In the first chapter we estimate biogas potential based on feedstocks of animal and plant origin - silage corn, chicken dung and pig and cattle manure. The amount of raw materials of animal origin is based on official statistics, whereby potential of the corn silage is estimated upon the assumption of substitution of land areas under the exported corn with sowing of silage corn for biogas production. In the second chapter we give an overview on the existing legislative framework for biogas production. The next section represents the profitability analysis of biogas production in Ukraine under the "green tariff" according to nine scenarios depending on three different feedstocks for production (corn silage, cattle and pig manure, chicken dung) and three different installed electrical capacities of the plants (for production of 0.5 MWel, 1 MWel and 3 MWel). Finally, we assessed the number of plants that might be built in Ukraine. The fifth section presents the calculations of financial state support, required by the assumption of the full realization of biogas potential in Ukraine for three types of plants and three types of feedstocks.

[2] http://www.fnr.de

2. Estimation of the biogas potential in Ukraine

Biogas originates from bacteria in the process of bio-degradation of organic material under anaerobic (without air) conditions. This type of biogas comprises primarily methane and carbon dioxide.[3] The energy content of biogas is directly dependent on the methane content. The higher the content of substances such as fats and starch that easily break down in the fermented mass, the greater the gas yield.[4]

There is a wide range of organic substrates for biogas production such as cattle and pig manure, chicken dung, various wastes (from plants, slaughterhouse, food industry, waste water, etc.), silage, rotten or brewer's grain, malt remnants, marc, distillery slop, sugar beet and fruit pulp, sugar beet tops, fiber and other starch and treacle production, milk whey, flotation sludge, dewatered flotation sludge from municipal waste water treatment plants, algae and others. Most of the raw materials can be differently combined in the production process.

Ukraine with its good agricultural basis has promising potential for biogas production. In our analysis we concentrate on the yields of biogas that can be generated in Ukraine from cattle manure, pig manure, chicken dung and silage corn as the most available agricultural sources.

BIOGAS OF ANIMAL MANURE ORIGIN

Cattle, pig manure and chicken dung are especially suitable feedstocks for biogas plants because of the methane producing bacteria already contained in the stomach of animals. The specific gas production, however, is lower and the content of methane is around 60-65% because of prefermentation in the stomach.[5]

Collection and removal of cattle and pig manure and chicken dung from farms is the subject of state regulation according to the State norms of technological designing.[6] The type of the removal (mechanical or hydraulic) also influences the content of the manure and its further energy characteristics. Furthermore, these State norms also define the values of output of excrements by cattle, pigs and chicken per day. In our analysis we take these values as the main source for defining biogas potential based on the number of livestock of agricultural enterprises in Ukraine.

In 2008 there were about 5.1 mln heads of cattle, 6.5 mln heads of pigs and 177.6 mln heads of poultry in Ukraine. A big number of cattle and pigs is still held by private households. Besides, there are a lot of small-scale agricultural enterprises that have a few livestock but cannot be considered as reliable suppliers of raw material because of complexity to collect animal waste from them. When we disregard private households in our estimation of potential, agricultural enterprises, which can be regarded as potential suppliers of raw materials (animal waste) for biogas production in Ukraine, account only for approximately 34% of cattle, 42% of pigs and 50% of poultry.

In order to ensure supply with raw materials for biogas plant with the installed electrical capacity of 0.5 MWel , at least 2 thd of (milk) cows, or 25 thd of permanent pig herd, or 250 thd of hens-layers (or 500 thd of broilers) are needed.[7] As of January 1, 2009 only about 3% of all agricultural enterprises in Ukraine had enough livestock to ensure biogas production with own raw materials. In particular, 107 agricultural enterprises had livestock herds above 2 thd heads; 199 had poultry herd above 50 thd heads and 65 had pigs herd above 6 thd of heads.[8] Other agricultural enterprises can be regarded as potential suppliers of animal manure for biogas production only if their output is grouped. In this case animal manure becomes a good with a certain monetary

[3] http://en.wikipedia.org/wiki/Biogas
[4] Biogas-and introduction. FNR 2008.
[5] Biogas Digest. Volume II. Biogas - Application and Product Development. Information and Advisory Service on Appropriate Technology. GTZ. http://www.gtz.de/de/dokumente/en-biogas-volume2.pdf
[6] ВНТП-АПК-02.05, ВНТП-АПК-01.05, ВНТП-АПК-04.05 , ВНТП-АПК-09.06
[7] According to the calculations of the biogas plant construction company
[8] It is unknown how many of 199 poultry producing enterprises or of 65 pig producing enterprises have a herd size above 250 thd of hens or 25 thd of pigs respectively. It is only known that 199 poultry producing enterprises all together keep above 85 mln of poultry heads and make up the largest portion of agricultural enterprises involved in poultry production. 65 pig producing enterprises keep together 936 thd of pigs.

value on the market. Besides, a biogas producer should bear significant logistical costs to collect and deliver this manure to the biogas plant.

By March 20, 2009 Ukrainian agricultural enterprises in total had about 3.1 m t manure of cattle origin, 0.874 mln t of pig manure and 0.558 mln t of poultry dung.[9] On average manure can contain 75% of water depending of the type of its collection and the type of the livestock. Therefore, it is more accurate to use data based on dry manure to calculate potential biogas yields. The quantity of manure given by an animal also depends on its age. Taking all this into account, we calculated dry manure output per different age groups of cattle and pigs (see Table 1).

Table 1

Calculation of biogas potential in Ukraine based on amount of volatile substances (VS)[10]

	Number of animals in agricultural enterprises, thd heads (as of 2008)	Amount of VS per head, kg/24h	Total amount of VS in Ukraine, tons/24h	The degree of fermentation of VS, units	Biogas yield per kg of VS, m^3/24h	Total biogas yield, thd m^3/24h
	A	*B*	*C=A*B*	*D*	*E*	*F=C*D*E*
Total cattle	*1720.1*		*5890.32*	*0.35*	*0.4*	*824.644*
cows	624.3	5.29	3302.55			
calves under 1 year	425.2	0.88	374.176			
cows of 1-2 years	85.2	3.02	257.304			
cows from 2 years and older (sired)	85.8	5.29	453.882			
cows from 2 years and older (unsired)	46.9	5.29	248.101			
bulls-producers	2.5	4.7	11.75			
other cows and bulls	450.2	2.76	1242.55			
Total Pigs	*2730.9*		*1442.71*	*0.4*	*0.8*	*461.67*
Main sows	226.7	0.93	210.831			
Sows that are being checked	92.7	0.75	69.525			
Remount piglets over 4 months	135.6	0.65	88.14			
Piglets under 2 months	647.4	0.041	26.5434			
Other pigs	1628.5	0.643	1047.67			
Hens and cocks	*85720*	*0.036*	*3085.92*	*0.45*	*0.9*	*1249.8*
Total			**10418.9**			**2536.1**

Source: Own calculations based on National Agrarian University and State Statistics Committee of Ukraine data.

Total dry manure potential that could be obtained from all livestock of cattle, pigs and hens in Ukraine is 12.5 thd tons per 24 hours. Total crude manure potential is 84.8 thd tons per 24 hours (for details see Annex E). The humidity of crude manure and the manure used in biogas plants differs. Therefore, our calculations are based on the conservative methodology of volatile

[9] According to the data of the Ministry of Agrarian Policy of Ukraine from March 2009.

[10] VS = DM - (1 - ASH), where VS is volatile substances (kg per head for 24 h), DM is dry manure (kg per head for 24 h), ASH is share of ashes in manure (coefficient).

substances, which takes into account dry matter of the substrate. Thus from the existing amount of dry matter of manure in Ukraine could be produced 2.5 mln m^3 of biogas per 24 hours. Another approach to calculate potential biogas yields is shown in Annex E.

Given herd number and age structure of animals in 2008[11] **Ukrainian annual potential of biogas produced from cattle and pig manure and chicken dung will make up 926 mln m^3**. When 1 m^3 of biogas could be converted to 1.5-3 kWh of electricity[12], 926 mln m^3 can be transferred to about 1.39-2.78 bn kWh of electricity, around 1% of current electricity production in Ukraine.[13]

BIOGAS OF PLANT ORIGIN

There are a lot of substrates of plant origin that can be effectively used for biogas production. Moreover, energy crops have higher methane contents, than animal waste. In Comparison of silage corn with other energy crops, it has advantages in lower costs of growing and storing, possessing almost the same methane content (52%). Furthermore, biogas from corn silage implies the highest reductions in greenhouse gas emissions and the highest savings of fossil fuels. Also corn being ensiled can be preserved on the field up to one year with little losses in dry substance.[14] Due to these characteristics, we analyze the potential of generating biogas from silage corn in Ukraine rather than from other plants.

Corn for silage, green fodder and hay were planted on 512.9 thd ha with the harvest level of 9.2 mln t in 2008 in Ukraine. According to the State Statistics Committee of Ukraine average yield of corn silage is 17.9 t/ha and varies from 10 t/ha in Odessa region to 25 t/ha in Sumy region as well as upon the efficiency of production. Almost all the silage corn grown in Ukraine is directed to animal feed. Thus, as for today there is no corn for silage, green fodder and hay in Ukraine to use for biogas production.

In contrast, harvested area of corn for grain is almost 5 times higher and its total harvest in Ukraine is 1.3 times higher than by silage corn. In particular, the average yield of corn for grain in Ukraine was just 4.8 t/ha in 2008 that brought 11.5 mln t harvest from 2.4 mln ha of sown area. We should also note, that more efficient companies obtained 7,2 t/ha.[15]

To evaluate the biogas potential in Ukraine from silage corn, we keep the sown area under this crop unchanged and assume that:

- Grain corn that is not consumed in Ukraine will not be exported (for grounds please see Gross margin analysis of production of grain and silage corn in the Chapter 4)
- Land, that is used under the exported corn, will instead be used for silage corn for further biogas generation.
- Carry-over stocks remain constant [16]

[11] It should be noted that structure and number of animals is constantly varying, thus calculated biogas potential can be viewed as a reference point, and some deviations from it are possible. Also, taking into account that different age groups of pigs and livestock give different amount of manure, we received much lower values of biogas yield per animal head and much higher biogas yield per manure amount in comparison with averages.

[12] FNR (2008). Biogas – an introduction.

[13] In 2008 Ukraine produced 192.6 bn kW of electricity
http://ukrstat.gov.ua/control/uk/localfiles/display/operativ/operativ2009/pr/etgv/etgv_u/elbal_u.html

[14] Thyø K. and H. Wenzel (2007). Life Cycle Assessment of Biogas from Corn silage and from Manure. Report, Institute for Product Development.

[15] Market information taken from agroholdings.

[16] Digesting corn-cob-mix, corns only or maize without corn and cob gives 43 – 70 % less methane yield per hectare, on which the biogas yield is dependent. Biogas should thus be produced from whole corn plants (for details see Amon T., V. Kryvoruchko, B. Amon, W. Zollitsch, E. Pötsch. Biogas Production from Corn and Clover Grass estimated with the Methane Energy Value System. University of Natural Resources and Applied Life Sciences and 3Federal Research Institute for Agriculture in Alpine Regions).

Table 2
Calculation of biogas potential in Ukraine from corn in 2008/2009 marketing year

Indicator	**Quantity**
Production, thd t	11400
Total Consumption, thd t	6250
Exports, thd t	4500
Share of Exports in Production, %	39%
Area Harvested under the Exported Share, thd ha	936
Yield of Corn for silage, green fodder and hay, t/ha	17.9
Potential Harvest of Corn that can be used for Biogas Production, thd t	16754.4
Biogas Yield m^3/t of silage corn	250*
Potential Biogas Production, mln m^3	4188.6

* Dy Matter content in silage corn is 35% and the biogas yield is the average yield from figures, build into specifications of biogas equipment proposed on Ukrainian market, that are 200-300 m^3/t.

Source: Own calculation based on USDA, State Statistics Committee of Ukraine, equipment provider data.

Therefore, as can be seen from Table 2, **the potential of biogas production calculated on the base of the amount of corn** that has been exported from Ukraine in 2008/2009 MY **could be 4.19 bn m^3** if the land, used to grow this grain corn would be instead used for growing silage corn with the average yield of 17.9 t/ha for silage corn instead of 4.7 t/ha for grain corn. Taking into account that 1m^3 of biogas on average could be converted to 1.5-3 kWh of electricity, using the estimated potential Ukraine could get 6.28-12.57 bn kWh of electricity annually. It is 3-7% of current Ukrainian electricity production.

However, under this assumption each farmer would have to estimate the opportunity costs of silage corn for biogas production. A pragmatic method to assess opportunity costs is the calculation of gross margins for each alternative use: a) grain corn for sales, b) corn silage for biogas production, and c) corn silage for feeding animals. In this case we compare the alternatives a) and b) (see Chapter 4).

3. Legal framework of biogas production in Ukraine

There are two main laws, which set the framework for biogas development in Ukraine - the Law of Ukraine "On the alternative types of liquid and gas fuels" (2000)[17]and the Law of Ukraine "On alternative sources of energy" (2003)[18]. The first one gives the basic definitions and characteristics of the alternative fuels, sets the main principles of the state policy in the area, which includes i.a. support of the entrepreneurship in the sphere of alternative arts of fuels, as well as defines administrative and economic stimulus for production and consumption of alternative fuels. The Law "On the alternative sources of energy" regulates the state administration and regulation in the field of alternative energy resources, organizational support, standardization and some general peculiarities of the use of the alternative energy resources. On March 15, 2006 the Cabinet of Ministers approved the Energy Strategy of Ukraine till 2030[19], which sets the goal to reduce the natural gas consumption in the country and increase the use of the renewable resource in the energy production. All the abovementioned documents are very general and don't introduce any clear and specific measures in the sector.

The first practical measure to promote the generation of power from alternative sources of energy was set in the Law N 601-VI "On amending some laws of Ukraine with regard to the introduction of a green tariff" [20] adopted by the Verkhovna Rada on September 25, 2008. The Law introduced amendments to the existing laws – "On electricity" and "On alternative sources of energy". According to the law the subject of the green tariff regulation is electricity, generated from the alternative sources. The definition of the "green tariff" is given in the amended Law "On electricity"[21] and says, that *"green tariff"* is a special tariff for electricity generated at the power plants that use alternative sources of energy (except blast-furnace and coke gases; with regard to hydropower – at small plants only, i.e. with capacity up to 10 MWel)[22].

Further, the amended Law "On electricity" obliges the Ukrainian wholesale electricity providers to purchase electricity generated at the power plants that use alternative sources of energy through the green tariff. The green tariff was planned as a double average tariff for traditional electricity[23] sold on the Ukrainian wholesale market in the year preceding the year of the tariff decision. The precise tariff rate is to be specified by the National Commission for Electricity Regulation (NCER) on a year basis. Also, the amended Law "On electricity" provides for a possibility for the power plants to sell electricity from alternative energy sources through the green tariff directly to consumers. In this case, consumers shall only receive a special document that would confirm their purchase of such electricity and would not lead to any other consequences.

Besides, according to the law the producer may also sell the electricity generated from alternative sources of energy at contractual prices to final consumers or to the energy supplying companies (Oblenergos). However, Ukrainian by-laws set administrative limitations on Oblenergos to buy the electricity at prices, which are higher, than the wholesale tariff. It is also explained by the fact, that there is no mechanism in Ukraine to compensate higher costs for Oblenergos for buying electricity through "green" tariff and thus to avoid price distortions, that may arise in regions with high amount of "green" power plants. So, there is no consistent legislative framework for Oblenergos to buy electricity form alternative resources directly from producers.

Final consumers may buy electricity from alternative resources directly from power plants either under the contracted prices or under the "green" tariff. However, there is no incentive for consumers to pay the "green" tariff except own environmental concerns. Power plants with higher

---

[17] Law of Ukraine "On the alternative types of liquid and gas fuels" from January 14, 2000 N 1391-XIV with amendments introduced by the Law of Ukraine from May 21, 2009 N 1391-VI

[18] Law of Ukraine "On alternative sources of energy" of 20 February 2003, No 555-IV with amendments introduced by the Law of Ukraine from September 25, 2008 N 601-VI

[19] Order of the Cabinet of Ministers from March 15, 2006 N 145-p

[20] Law "On amending some laws of Ukraine with regard to the introduction of a green tariff" from September 25, 2008 N 601-VI

[21] Law of Ukraine "On electricity" of 16 October 1997, No 575/97

[22] Comment on the Law of Ukraine No 601-VI "On amending some laws of Ukraine with regard to the introduction of a green tariff" by Justyna Jaroszewska

[23] E.g. on September 25, 2008, this tariff for electricity was 0.251 UAH/kWh.

capacity and lower production costs will be more flexible in terms of electricity sales prices and could go for contractual prices lower than "green" tariffs.

Figure 1 shows the existing mechanism of electricity sale under the green tariff. Green tariff actually becomes a consumer burden, as it will be paid be final consumers when the regulated tariffs are raised in the consequence of the rise of wholesale prices. Energy wholesale market "Energorynok" estimates the average wholesale prices for all the electricity bought from different generators. However, when the regulated tariff is raised, Oblenergo's margin will decrease as a consequence of growing average wholesale prices.

Figure 1 shows the current mechanism of electricity sale from alternative resources of energy in Ukraine.

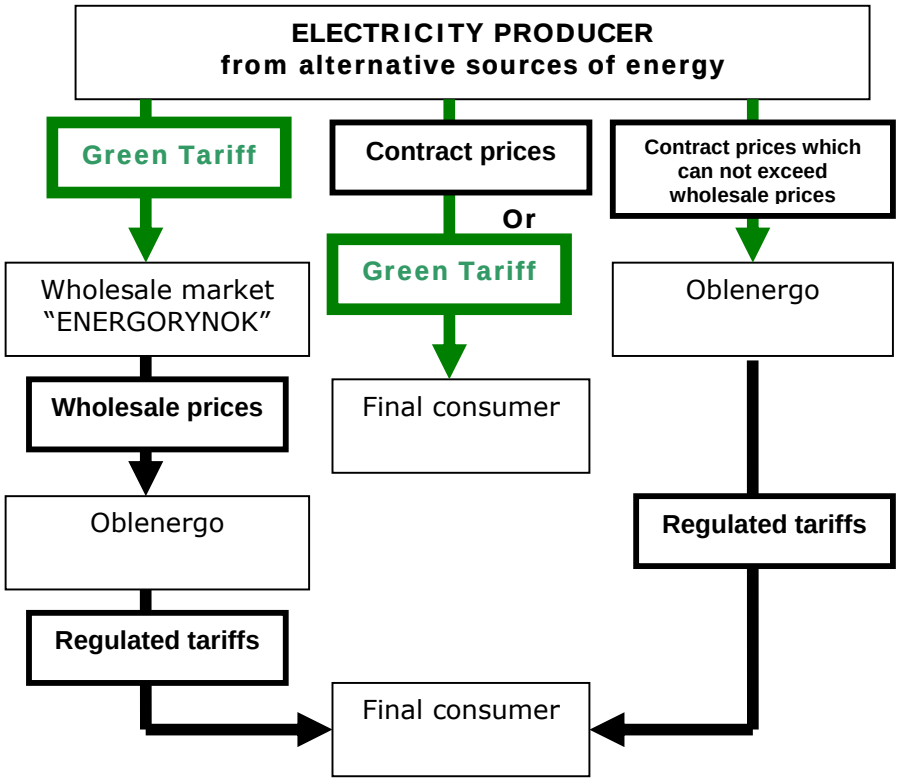

Figure 1. *"Green" tariff mechanism in Ukraine*
Source: Own presentation based on Ukrainian legislation.

In the beginning of 2009 the Cabinet of Ministers of Ukraine passed series of Orders, aimed at promoting and regulating the biogas production in the country and execution of the Law N 601-VI. Among these Orders there is a concept of the state program for development of production and use of biofuels in 2010-2014[24], directed at the solution of the problem of energy dependence via development of bioenergy. The concept states that biogas production allows benefiting both from energy production and use of biological fertilizers as by-product. Furthermore, payback period of the biogas plant based on the use of waste is estimated at three-four years. The execution of the program should lead to the increased biogas production from sludge to the level of 130 mln m^3, that can substitute approximately 78 mln m^3 of natural gas[25]. According to the Cabinet of Ministers Order N 256[26] the consumption of the natural gas in 2010 should be cut by 8127.6 mln m3 compared to the year 2008 mostly by thermal power plants for energy and heat production.

Order No 223-p "On the creation of the register of resources suitable for biogas production"[27] obliges Ministries and other central executive authorities as well as local administrations annually

[24] Order of the Cabinet of Ministers from February 12, 2009 No. 276-p
[25] Accounting that 1 m^3 of biogas equals approximately to 0.6 m^3 of natural gas.
[26] Order of the Cabinet of Ministers from February 19, 2009 No. 256-p
[27] Order of the Cabinet of Ministers from February 12, 2009 No. 223-p

to collect and report until March 25 to the NCER the information on the availability on the agricultural enterprises resources for biogas production. The reporting form, attached to the Order, includes information on the enterprise, amount and costs of the energy consumed as well as the list of the resources (animal waste, poultry manure, products of animal utilization, green mass, food wastes, hard domestic wastes and communal sewage). The NCER in its turn should accumulate the information and supply it to the National academy of sciences for recommendations on the volumes of biogas production in Ukraine. The register of resources for biogas production should be created until May 1 each year and the summarized information is to be made public. Production, storing and sale of biogas and liquid fuel from biomas is the subject of licensing by the Ministry of fuel and energy.[28]

On January 15, 2009 the NCER set the green tariff for the year 2009 on the level of 0.6624 UAH/kW*hour (without VAT), that is 0.7949 UAH/kW*hour (with VAT)[29] and a week later defined the procedure for setting, revision and cancellation of the green tariff for subjects of economic activity, which are licensed to produce electricity from alternative sources of energy. This procedure does not refer to those producers, combining alternative resources with traditional fuels.[30] The procedure gives the list of documents, which are necessary for the application procedure and has three reporting forms attached. Among those are the cost structure of production of electricity from alternative sources of energy as well as expected output. The applicant should also report on the cost of each kWh of the produced electricity.

In April 2009 the Ukrainian Parliament passed another Law "On amending some laws of Ukraine (with regard to promoting the use of alternative sources of energy)", which proposes several amendments to the Law "On electricity" regarding the green tariff and its establishment [31].

The law makes clear that state policy aims at supporting not only the development of wind energy but also all other renewable energy sources (except blast-furnace and coke gases; with regard to hydropower – at small plants only, i.e. with capacity up to 10 MWel). It obliges the National Commission for Electricity Regulation to establish and maintain a register of facilities of the energy system that use alternative sources of energy.

Further, the law underlines that the main instrument for supporting the development of alternative energy sources is a feed-in "green tariff". The law supplements the Law "On electricity" with a new article – Article 17-1 that stipulates the procedure for fixing the green tariff and changes the procedure of its calculation.

The green tariff shall be approved by the National Commission for Electricity Regulation for 1) each company that produces electricity from alternative sources of energy, 2) for each type of alternative energy and 3) for each facility.

The rate of green tariffs for producers that produce electric energy from wind energy, biomass, solar energy and hydro-power shall be based on the level of the January 2009 retail tariff for electricity for second-class consumers multiplied by the relevant coefficient for a specific energy source.

The coefficient shall vary according to energy source as well as the capacity of the power plant (in case of wind and solar energy) and the place where facilities are installed (solar energy).

The coefficient has been set:

- at 1.2 – for electric energy produced from wind (with the plant capacity that does not exceed 600 kWel);
- at 1.4 – for electric energy from wind (600 kWel – 2000 kWel);
- at 2.1 - for electric energy from wind (the capacity exceeds 2000 kWel);
- at 2.3 – for electric energy from biomass [32];

[28] Decree of the Cabinet of Ministers N 829 from July 29, 2009
[29] NCER Regulation from January 15, 2009 No. 25
[30] NCER Regulation from January 22, 2009 No. 32
[31] Law of Ukraine "On amending some laws of Ukraine (with regard to promoting the use of alternative sources of energy)" N 1220-VI from April 1, 2009

- at 4.8 - for electric energy from solar energy (for onland facilities);
- at 4.6 - for electric energy from solar energy (for facilities installed on roofs, with the capacity over 100 kWel);
- at 4.4 - for electric energy from solar energy (for facilities installed on roofs, with the capacity that does not exceed 100 kWel);
- at 0.8 - for small hydropower stations.

According to the retail tariff for electricity for second-class consumers in 2009, the green tariff for electric energy from biomass is 1.3446 UAH/kWh excluding VAT and 1.6135 UAH/kWh including VAT.

The law also stipulates reduction of the coefficient for facilities commissioned (or substantially modernized) after 2014, 2019 and 2024 by 10%, 20% and 30% respectively.

Thus, for the facilities, producing electric energy from biomass, which would be commissioned (or substantially modernized) after 2014, the level coefficient would be 2.07, after 2019 – 1.84 and after 2024 – 1.61.

Substantial modernization means that modernization costs exceed 50% of the initial value of the equipment. Other alternative sources of energy such as geothermal sources, waves, etc. has not been considered by the law.

This procedure applies under the condition that from 1 January 2012 the share of materials, works, services and equipment of Ukrainian origin used for construction of a facility producing electric energy from alternative energy sources is not less than 30% of its total value and from 1 January 2014 – not less than 50%. Some additional requirements have been introduced for producers of solar energy.

The green tariff shall be applied until 1 January 2030. In case of changes to the procedure on the green tariff, producers may stick to the tariff established under the previous procedure but will have also the possibility to follow the new rules.

The law also sets the fixed "minimal" value of the green tariff, bound to Euro at the exchange rate of the National Bank of Ukraine on January 1, 2009 (i.e. 1 euro = UAH 1085,5460). All further values of green tariff should exceed the "minimal" value of the green tariff in its hryvna equivalent for the certain date at the current official exchange rate of the National bank.[33] This mechanism is designed to protect investors from devaluation of hryvnia.

On 23 July 2009 the National Commission for Electricity Regulation approved[34] the fixed minimal green tariff. Table 3 shows the green tariff scheme with tariff coefficients, fixed minimal tariff and its bound rate in Euro.

---

[32] **Biomass** – is biologically renewable substance of organic origin, that is biologically digestive (agricultural wastes (**from plant growing and animal breeding**), forestry and technologically connected to it industrial sectors, as well as **organic part of industrial and domestic wastes**. According to the law of Ukraine "On the alternative types of fuels" from January 14. 2000 with amendments from 21.05.2009 This means, that any substrates, which correspond to this definition can suit as a feedstock for biogas production to fall within the purview of the "green tariff" law.

[33] Review of laws and draft laws initiated and considered by the Verkhovna Rada (Parliament) of Ukraine in March 2009 by Justyna Jaroszewska and the Law Firm Sofiya.

[34] NCER Regulation from July 23, 2009 No 857

Table 3

Green tariff scheme

Origin of electric energy	Tariff coefficient 2009	Tariff level 2009 without VAT (UAH Kop/kWh)	Euro binded minimal tariff level 2009 without VAT (EUR cent/kWh)	Tariff coefficient 2015 (-10%)	Tariff coefficient 2020 (-20%)	Tariff coefficient 2025 (-30%)
Wind (plant capacity under 600 kWel)	1.2	70.15	6.46	1.08	0.96	0.84
Wind (600 kWel – 2000 kWelel)	1.4	81.84	7.54	1.26	1.12	0.98
Wind (over 2000 kW)	2.1	122.77	11.31	1.89	1.68	1.47
Biomass	2.3	134.46	12.39	2.07	1.84	1.61
Solar energy (onland facilities)	4.8	505.09	46.53	4.32	3.84	3.36
Solar energy (facilities installed on roofs, capacity over 100 kWel)	4.6	484.05	44.59	4.14	3.68	3.22
Solar energy (facilities installed on roofs, capacity under 100 kWel)	4.4	463.00	42.65	3.96	3.52	3.08
Small hydropower stations	0.8	84.18	7.75	0.72	0.64	0.56

Source: NCER Regulation from July 23, 2009 No 857, Law of Ukraine N 1220-VI from April 1, 2009

The National Commission adopted amendments to the "Procedure of setting, revising and abolition of the "Green" tariff for subjects of economic activity" [35] in July 2009. The procedure sets, that stimulation mechanism for electricity production from alternative sources of energy refers to licensed producers of electricity only or producers of combined electricity and heat. Each interested company shall apply to the Commission for approval of a concrete green tariff, effective for this concrete company. The application package was widened comparing to the previous list and above the detailed cost structure the applicant should also provide the commission reasoning and proved of each line of costs (copies of purchase contracts, invoices, cost calculations etc.). NCER has 30 days to examine the application and additional 15 days for approval the "green" tariff. The licensees should quarterly report the commission on their activity.

As of September 2009 the NCER has no application from electricity producers from biomass under the "green" tariff. It has only set the value of the "green" tariff on the level of UAH 123.22 kop./kWh without VAT for four electricity producers form wind energy and on the level of UAH 84.49 kop./kWh for 28 small hydropower stations, whereby there two juridical persons, which own 11 and 15 of hydropower stations respectively, one physical person – entrepreneur and one closed joint stock company.

In May the Parliament adopted Law amending legislation in order to promote production and use of biological fuels.[36] The Law comes into force on January 1, 2010 and provides for 9 year waiving

[35] NCER Regulations from July 16, 2009 No. 828

[36] Law of Ukraine 1391-VI from 21.05.2009

from profit tax on profit from own produced biofuels sale and from import duty and VAT tax on equipment for biofuel production and on vehicles, which consume biofuels and are not produced in Ukraine. The act also abolishes state monopoly on spiritus plants for bioethanol production.

Feeding the electricity produced from the alternative sources into the electricity network

The National Commission for Electricity Regulation has to approve the sample agreement on feeding in to the electricity network of the producers of electricity from alternative sources and the agreement of purchase-sale of electricity from alternative sources of energy[37].

The point of feeding-in of electricity is the border of the land lot, on which the plant is situated, or upon the agreement of the owner, on the territory of the plant.

NERC has approved samples of contract forms and technical norms for feeding in to the electric network the power plant, which produces electricity from alternative resources, and sample contract forms between state enterprise "Energorynok" and electricity producer from alternative resources. The commission has also developed sample contracts between the consumer, supplier and producer of electricity from alternative sources. According to the contract forms the point of electricity sale is the border point of accounting attribution and is stated in the Differentiation act of the accounting attribution. [38]

The Law "On amending some laws of Ukraine (with regard to promoting the use of alternative sources of energy)" also states that suppliers of energy have no right to refuse producers of energy from alternative energy sources the access to their distribution grids. Moreover, suppliers of energy shall provide for expenses for feeding-in the facilities that produce energy from alternative energy sources in their investment plans.

[37] The Order of the Cabinet of Ministers "On ways of feeding in to the electric networks the object of electricity, which produces electricity using alternative sources" from February 19, 2009 N 126
[38] Nerc Regulation from July 16, 2009 No. 838

4. Estimation of profitability of biogas production in Ukraine

To estimate the profitability of biogas production in Ukraine under the green tariff[39] we compare costs and benefits of operation of biogas plants of three different installed electrical capacities (0.5 MWel, 1 MWel and 3 MWel), which process three different types of feedstocks for biogas production (cattle and pig manure, chicken dung and silage corn). Thus, we analyze nine different cases of profitability of biogas production. In our model we use plain feedstock to keep the calculation simple, although substrates can be differently combined by biogas production, giving different yields and requiring different types of equipment (mainly different fermenter volume). In practice producers more often combine the feedstocks, however interested investors can use our tables to compare various opportunities and combinations of feedstocks.

The major groups of costs in the calculations are production, and operational and maintenance costs. Production costs are costs for purchase of equipment for biogas production and electricity generation (plant itself) as well as of land needed to place the plant, costs for personnel, electricity, heat and water consumption. Operational and maintenance costs include costs to regularly provide the biogas plant with raw materials and annual maintenance and repair costs of the equipment. Transport costs are included in the feedstock costs. Other costs are case specific (administrative costs range from 2% to 10% of total benefit, some other additional transaction costs, etc.). Those are excluded from the calculations.

Benefits that can be obtained from biogas production are generated from the sale of electricity (produced from biogas and sold by green tariff). Bio-fertilizer is a by-product of biogas production and we can also consider benefits from it sales or own use. The detailed description of each category of costs and benefits of biogas production is given in Annex A and results of detailed calculations of the profitability of different scaled biogas plants, using different types of feedstocks can be seen in Annexes B, C and D. Here we will only focus on the main obtained results.

COST-BENEFIT ANALYSIS OF BIOGAS PRODUCTION FROM CORN SILAGE

We consider three types of biogas plants according to the installed electrical capacity of 0.5 MWel, 1 MWel and 3 MWel with the working period of the next 15 years. The investment period for construction and preparatory works for production is "year 0" (12 months). Specific figures of costs and benefits of the three scales of plants which produce biogas from corn silage are given in the Annex B. Figure 2 shows the main indicators to judge the profitability of the project.

With the increase of capacity of the plant, the difference between costs and benefits increases in the positive direction, making NPV and IRR higher, and payback period lower. Depending on the feedstock price and biogas plant electrical capacity, NPV varies from 12.2 to 79.8 mln UAH when the interest rate is on the level of 12%[40]. When the interest rate is on average market level and equals 28%, NPV is negative for the small-scale biogas plant of the capacity of 0.5 MWel. With scale increase to 1 and 3 MWel, NPV grows to 3.5 and 26.4 mln UAH respectively. IRR is varying from 25% to 39% depending on the considered option. The payback period lies in the interval of 2.6-3.9 years.

[39] Multiplying the coefficient by the tariff for electric power for consumers of the 2nd class of voltage (as noted as a base for the green tariff calculation in the Law) and adding the VAT tax we get 1.61 UAH/kW*h as the green tariff that we use in our calculations.

[40] This level might be granted by trade finance schemes of equipment suppliers and banks.

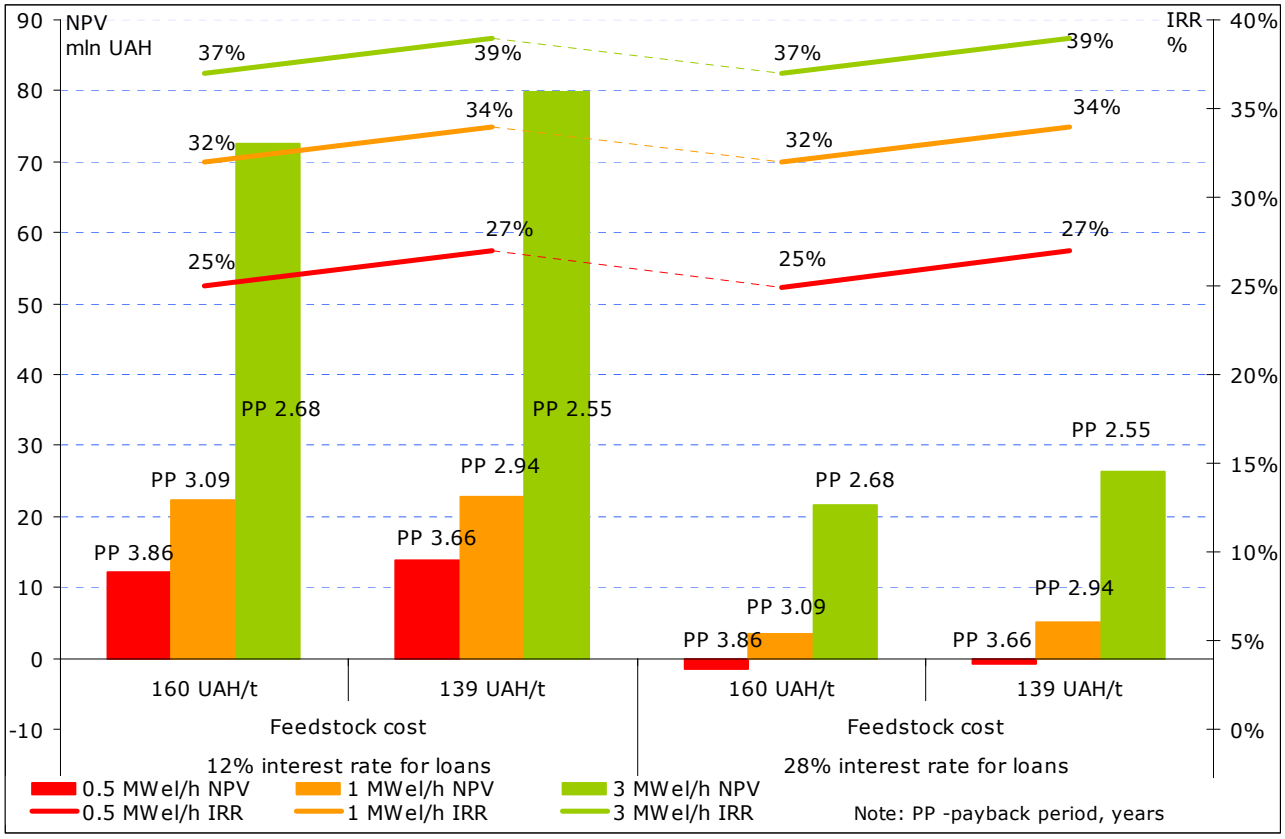

Figure 2. *Profitability indicators of the biogas plants of 0.5 MWel, 1 MWel and 3 MWel installed electric capacity using corn silage as a feedstock*
Source: Own representation.

The results show that investments in biogas plant of 0.5 MWel installed electrical capacity pay back in about 3.9 years, and for 15 years of operation the excess of cash flows can reach 12-14 million UAH in present value terms, under the condition that the loan may be taken at a special interest rate of 12%.[41] If the investor goes for the average market interest rate for loan of 28%[42], the biogas plant with the installed electrical capacity of 0.5 MWel is not worth investing since its NPV is below zero. Moreover, the obtained internal rate of return of 25-27% is lower than the market interest rate of 28%.

Investing in biogas plants with the electrical capacities of 1 MWel and 3 MWel is more profitable. Due to economies of scale biogas plant of 3 MWel brings higher than 0.5 MWel biogas plant. Its internal rate of return is almost reaching 40% that means a profitable investment even under current capital market conditions.

By-profit from bio-fertilizers

Additional profit can be obtained from sale or own use of bio-fertilizers that are a by-product of biogas production. This profit however is very conditional as depends upon the big number of factors, including existence of market, which is currently absent, and comparative advantages of bio-fertilizers toward conventional ones. If we consider the profit of bio-fertilizers sale we get following figures:

- for 0.5 MWel plant NPV is between 18.8 and 52.8 mln UAH. IRR is 61%-63%. Payback period is up to 1.64 years;
- for 1 MWel plant NPV is between 44.3 and 85.7 mln UAH. IRR is 76%-78%. Payback period is 1.30-1.32 years;

[41] Such credit rate is possibility under special trade finance credit programs or by equipment sellers.
[42] Average interest rate on the capital market as of August 2009.

- for 3 MWel plant NPV is between 145.6 and 271.4 mln UAH. IRR is 88%-90%. Payback period is 1.12-1.15 years.

The profit obtained from possible bio-fertilizers sale is rather big (above 7 mln (solid biofertilizers) and 700 thd (liquid biofertilizers) for 0.5 MWel capacity plant. It is above 14 mln and 1.4 mln respectively for 1 MWel plant and above 43 mln and 4 mln respectively for a 3 MWel capacity plant. Such profit for solid bio-fertilizer sale is achieved because they are dried to the solid stand suitable for sale with the heat, cogenerated by the electricity production.[43] However, the market of bio-fertilizers obtained during biogas production is not yet developed in Ukraine. That is why we do not account those profits into our base case scenario and leave them for investor considerations.

Gross margin analysis of production of grain and silage corn

An important practical question to be answered is whether grain corn production for sale on the market is more competitive towards silage corn for biogas production. To answer this question we calculate and compare gross margins for silage corn and grain corn (see Tables 3, 4).

In our calculations we differentiate between agriholdings with higher scale, efficiency and yields (30 t/ha for silage corn and 7.2 t/ha for grain corn) and comparatively less efficient average farmers (17.9 t/ha for silage corn and 4.7 t/ha for grain corn). Receiving higher yields, agriholdings invest however twice as much into the planted area as smaller farmers.

Table 3

Gross margin calculations for silage corn

Biogas plant electrical capacity, MWel	Amount of silage corn needed for biogas prod-n per year, t[44]	Net profit of a biogas plant not accounting for feedstock cost, UAH	Profitability of biogas plant per ton of silage corn, UAH/t	Revenue of silage corn in biogas plant, UAH/ha		Total costs for silage corn per ha of seeded area, UAH/ha		Gross margin of silage corn, UAH/ha	
				Agriholding	Farmer	Agriholding	Farmer	Agriholding	Farmer
0.5	10950	6114572	558	16752	9996	3006	1417	13746	8579
1	21900	12571521	574	17221	10275	3006	1417	14215	8859
3	65700	37934970	577	17322	10335	3006	1417	14316	8919

Source: Own calculations.

Table 4

Gross margin calculations for grain corn

FOB price of grain corn, Ukraine, USD/t	NBU's exchange rate, UAH/USD by 09.09.09	FOB price of grain corn, Ukraine, UAH/t	Revenue of grain corn, UAH/ha		Total costs for grain corn per ha of planted area, UAH/ha		Gross margin of grain corn, UAH/ha	
			Agriholding	Farmer	Agriholding	Farmer	Agriholding	Farmer
150	7.997	1199.55	8636.76	5637.89	5414.85	2713.00	3221.91	2924.89

Source: Own calculations.

The difference between the gross margins of silage corn for biogas production and grain corn is significant, proving that growing silage corn with its further use for biogas production have higher gross margins than growing grain corn for sales. This calculation is made under the assumption that FOB price for grain corn is 150 USD/t and the exchange rate is 8 UAH/USD. Assuming that the exchange rate would remain at the current level (8 UAH/USD), if FOB price for grain corn grows above 330-340 USD/t, export of grain corn will become more advantageous than growing silage corn for biogas production. Following a pessimistic scenario, if the exchange rate reaches

[43] See Annex A "Cost of heat consumption".

[44] By the ratio:1t of silage corn equals 200 m^3 of biogas and 1 m^3 of biogas equals 2 kWh electricity.

12 UAH/USD, the advantageous export price for grain corn would be at the level of 220-225 USD/t and producers should prefer to produce grain corn for export.

COST-BENEFIT ANALYSIS OF BIOGAS PRODUCTION FROM PIG AND CATTLE MANURE

Benefits of the plants producing biogas using pig and cattle manure as a feedstock are depicted on the figure below.

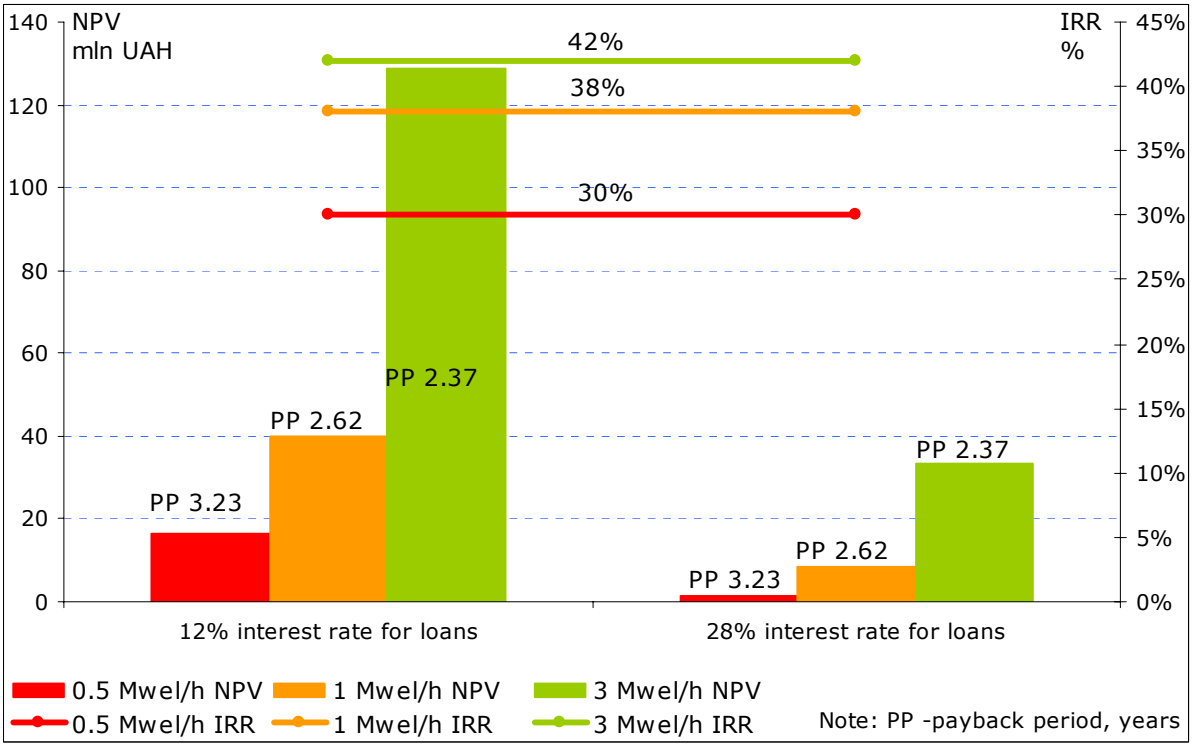

Figure 3. *Profitability indicators of the biogas plants of 0.5 MWel, 1 MWel and 3 MWel installed electric capacity using manure as a feedstock.*
Source: Own representation.

Production of biogas from cattle and pig manure appears to be more profitable than from corn silage. The payback period is shorter, NPV and IRR values are higher. In this case the payback period is 2.4-3.2 years; NPV values reach 16.5, 40 and 129 million UAH for the plants of installed electrical capacities of 0.5 MWel, 1 MWel and 3 MWel respectively (under the interest rate of 12%). If the interest rate is 28%, NPVs are above 1, 8 and 33.5 mln UAH. IRR also prevail over the current deposit rates in Ukraine. All together it makes the option of investments into the biogas plants on manure attractive at current capital market rates.

By-profit from bio-fertilizers

It should be noted that benefit from the electricity sale by green tariff is approximately equal for cases of biogas production from corn silage and cattle and pig manure. At the same time benefit from sale of solid bio-fertilizers or opportunity costs are higher by more than 2.5 times for the case of cattle and pig manure as a substrate for production. Thus, if we find a market for manure bio-fertilizers we can additionally earn above 29, 55 and 167 mln UAH by plants of 0.5 MWel, 1 MWel and 3 MWel respectively. Moreover, here we can notice that the benefit from sale of bio-fertilizers is 3.7 times higher than the one obtained from the electricity sale by green tariff. In particular:

- for 0.5 MWel plant NPV is between 77.5 and 162.7 mln UAH. IRR is 173%. Payback period is 0.58 years;
- for 1 MWel plant NPV is between 153 and 316.7 mln UAH. IRR is 201%. Payback period is half a year;
- for 3 MWel plant NPV is between 467 and 760 mln UAH. IRR is 218%. Payback period is 0.46 years.

Detailed table of figures for biogas plants of the three given capacities using cattle and pig manure as a feedstock is given in the Annex C.

COST-BENEFIT ANALYSIS OF BIOGAS PRODUCTION FROM CHICKEN DUNG

Profitability of the plants producing biogas from chicken dung is shown in the Figure 4.

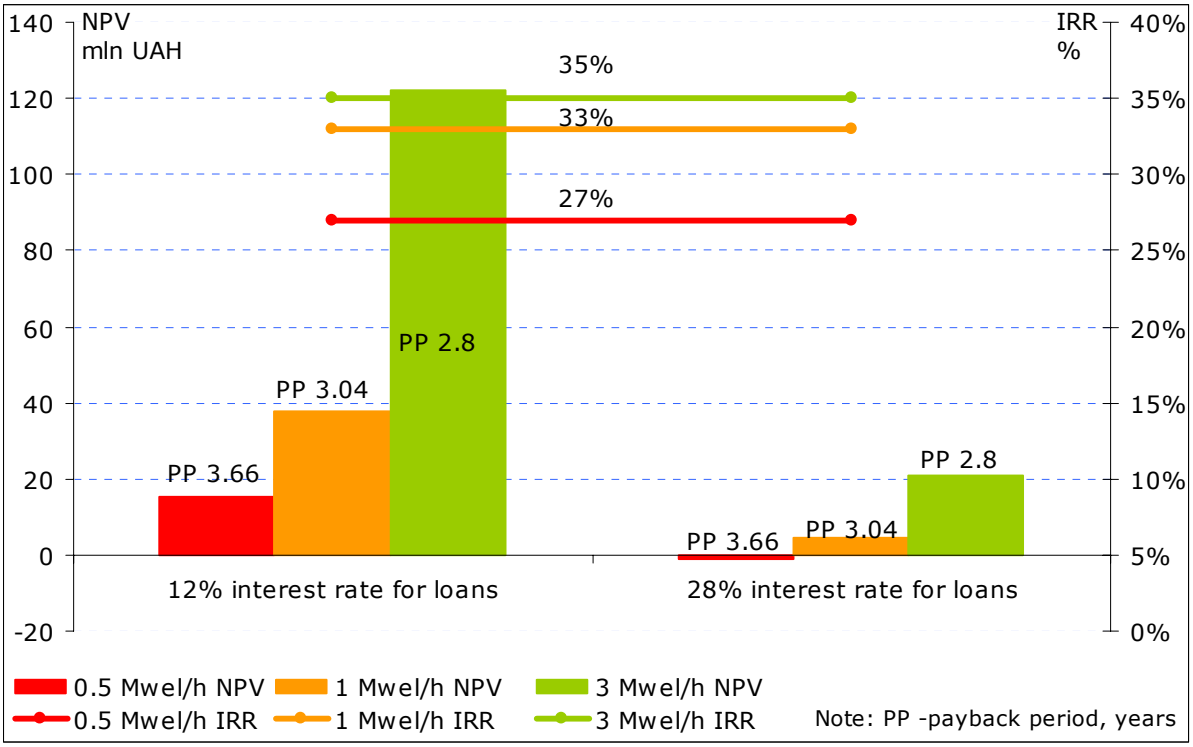

Figure 4. *Profitability indicators of the biogas plants of 0.5 MWel, 1 MWel and 3 MWel installed electric capacity using chicken dung as a feedstock.*
Source: Own representation.

Comparing the option of biogas production from chicken dung with cattle and pig manure and corn silage, we can see that it is less profitable than biogas production from cattle and pig manure but more profitable than production from corn silage.

The benefit from the sale of the electricity produced by the set green tariff is equal for all considered raw materials and remains at the level of about 7 mln UAH/year for the biogas plant of 0.5 MWel installed electrical capacity, 14 mln UAH/year for the biogas plant of 1 MWel installed electrical capacity, and 42 mln UAH/year for the biogas plant of 3 MWel installed electrical capacity.

If chicken dung is used as a raw material for biogas production, the payback period varies from 86 to 111 months. IRR will grow by 6% and 2% upon capacities, and will be from 27% (for a 0.5 MWel plant) to 35% (for a 3 MWel plant) that in average prevails over the current capital market rates. It also prevails over the applied interest rate of 28% for 1 MWel and 3 MWel plants. As expected, NPV is growing from above 15 mln UAH to 122 mln UAH (and from -1 to above 21 mln UAH when the interest rate is 28%) with the increase of the plant capacity. Detailed model calculations can be found in Annex D.

By-profit from bio-fertilizers

When we consider earning from bio-fertilizers sale or own use, NPV values achieve 36-66 mln UAH (as compared to -1-15 mln UAH without bio-fertilizers) for 0.5 MWel biogas plants, 78-138 mln UAH (as compared to 4-38 mln UAH without bio-fertilizers) for 1 MWel biogas plants, and 241-421 mln UAH (as compared to 21-122 mln UAH without bio-fertilizers) for 3 MWel biogas plants. IRR values fluctuate from 84% to 107% and payback period drops to a year or even lower.

Figure 5 shows cost of production of 1 kWh of energy for three different sizes of plants and three different types of feedstocks. The gap between the cost of energy produced by biogas plants and the green tariff is rather big, being the evidence of high profitability that could be drawn by biogas producers in Ukraine. It also shows the huge price difference Energorynok should cover to fulfill its obligations to actually pay the "green tariffs" to producers.

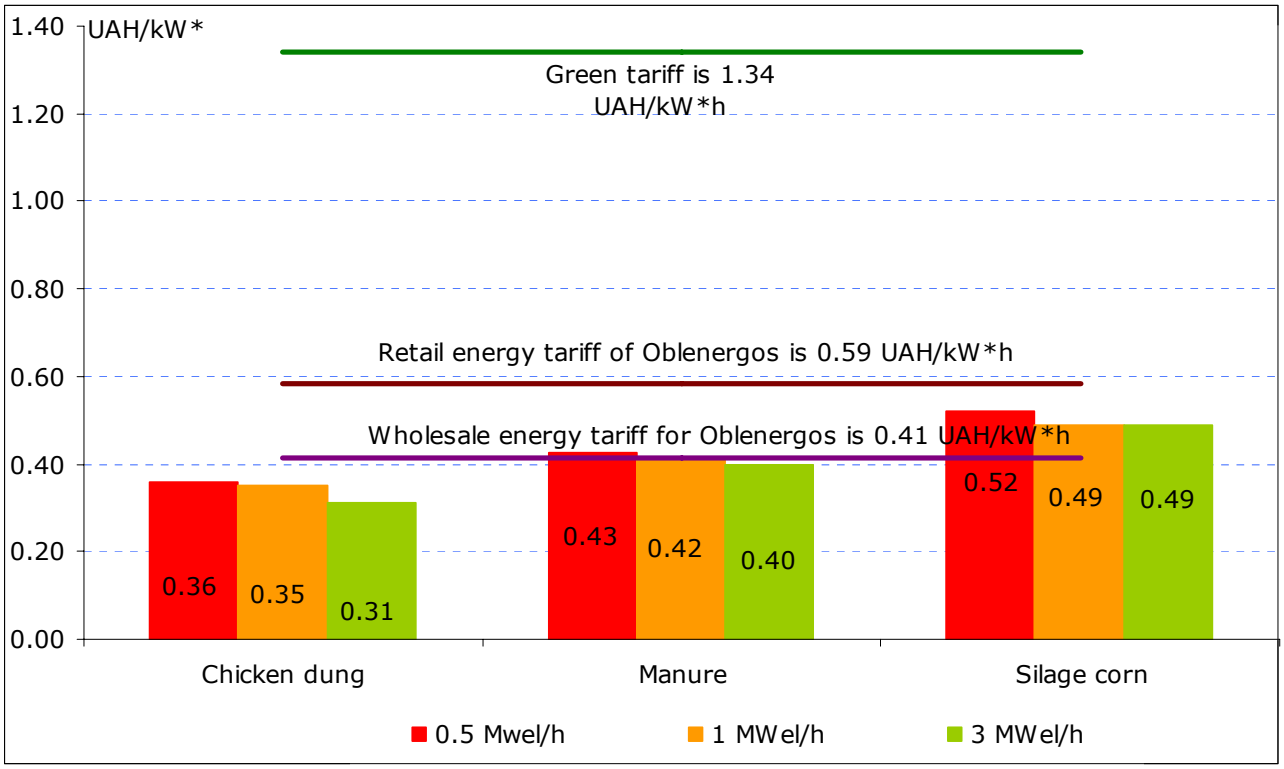

Figure 5. *Energy unit cost depending on the biogas plant electricity capacity and the feedstock used*

Source: Own calculations and the data from National Electricity Regulatory Commission of Ukraine and the Green Tariff Law.

Manure appears to be in the middle because of its lowest price per unit as an input as compared to chicken dung and corn silage. At the same time pig and cattle manure gives the lowest biogas output compared to other feedstocks analyzed.[45] Thus, chicken dung and pig and cattle manure are the most profitable feedstocks for biogas production.

We would like to conclude, that under the level of green tariffs set by the Ukrainian Government and under the assumption that biogas producers actually receive this money in full and considering given market conditions, biogas production using any kind of analyzed feedstock and by plants from 1 MWel and higher electrical capacities can be considered profitable in Ukraine. Biogas plants of 0.5 MWel capacities that work on corn silage and chicken dung under the current market interest rate of 28% are not profitable.

[45] Cattle manure gives biogas yield of 60 m3/t, pigs manure – 65 m3/t, chicken dung – 70-130 m3/t and corn silage – 200-300 m3/t. See http://zorgbiogas.ru/biogazovye-ustanovki/biogazovye-ustanovki

Table 5
Profitability comparison of biogas plants

Feedstock used	Feedstock price, UAH/t	Biogas plants electrical capacity					
		0.5 MWel		1 MWel		3 MWel	
		12% interest rate	28% interest rate	12% interest rate	28% interest rate	12% interest rate	28% interest rate
Silage corn	160	marginally profitable	not profitable	profitable	profitable	very profitable	profitable
	139	marginally profitable	not profitable	profitable	profitable	very profitable	profitable
Manure	35	profitable	profitable	profitable	profitable	very profitable	profitable
Chicken dung	50	marginally profitable	not profitable	profitable	profitable	very profitable	profitable

Source: Own calculations

How many biogas plants could be built in Ukraine?

Looking at our calculations of the biogas potential, there are 8778.4 thd t of dry manure and 3686 thd t of dry chicken dung available in Ukraine each 24 hours for biogas production. However, in the biogas production process they are watered. Thus, using dry matter for the calculation of potential number of biogas plants is a very conservative approach and gives very conservative picture of possible biogas production in Ukraine. Therefore, to assess the number of biogas plants we use crude manure output data, calculated in Annex E. There are 74.55 thd t of pig and cattle crude manure and 10.29 thd t of chicken dung available in Ukraine each 24 hours for biogas production. Additionally, Ukraine could have 17148.2 thd t of silage corn for biogas production (see calculations of potential).

Taking into account that biogas plants of 0.5 MWel, 1 MWel and 3 MWel capacities need 100, 200 and 600 t of manure, or 50, 100 and 300 t of chicken dung per 24 hours, or about 11, 22 and 66 thd t of silage corn per year [46] (see table 6), we can calculate that in Ukraine could be built:

- about 205 plants on chicken dung of 0.5 MWel electricity capacity, or 102 of 1 MWel electricity capacity, or 34 of 3 MWel electricity capacity;
- about 745 plants on cattle and pig manure of 0.5 MWel electricity capacity, or 372 of 1 MWel electricity capacity, or 124 of 3 MWel electricity capacity.
- and about 1566 plants on corn silage of 0.5 MWel electricity capacity, or 783 of 1 MWel electricity capacity, or 261 of 3 MWel electricity capacity.[47]

[46] We assume biogas plants work on imported equipment, according to specification of which cattle and pig manure have 60 m3/t biogas yield, chicken dung (layers) – 130 m3/t and corn silage – 200 m3/t.
[47] It is possible to apply another approach here. According to State Statistics Committee of Ukraine information 3741.4 thd ha of land was not sown in 2008. Taking into account average yield of silage corn in Ukraine of 17.9 t/ha (that we applied for farmer when calculating the price of silage corn), from the above mentioned unseeded land we could get 67 mln t of silage corn in 2008. 6116 of biogas plants of 0.5 MW/h electricity capacity, or 3058 of 1 MW/h electricity capacity, or 1019 of 3 MW/h electricity capacity can operate on 67 mln t of silage corn per year. It means daily 3058 thd kW/h or yearly 26.8 bn kW/h of additional electricity for Ukraine. If we apply agriholding silage corn yield of 30 t/ha we could get much more electricity for Ukraine. However, it remains questionable whether this unsown land of 3741.4 thd ha is really possible to use to grow silage corn.

Table 6
Amount of substrates needed for operation of biogas plants

Biogas plant electrical capacity, MWel	The amount of needed silage corn, t/year	The amount of needed pig and cattle manure, t/year	The amount of needed chicken dung, t/year
0.5	10950	36500	18250
1	21900	73000	36500
3	65700	219000	109500

Source: Own calculations.

Such number of plants could potentially annually generate about 11 bn kWh of electricity. In particular, biogas plants operating on pig and cattle manure – 3.26 bln kWh, on silage corn – 6.86 bn kWh, and on chicken dung – 897.9 mln kWh. This is 5.8% of annual Ukrainian electricity production.

Table7
"Green" energy production in Ukraine

		Theoretical potential		**Practical potential**
		Calculations based on dry manure (dry volatile substance methodology)	Calculations based on fresh manure (standard biogas output)	Calculations based on biogas equipment provider characteristics
Pig and cattle manure	biogas yield, m^3/24h	1,286,312.0	3,573,039.6	4,464,000.0
	electricity generation, kWh a day	1,929,468.0 – 3,858,936.0	5,359,559.4 – 10,719,118.8	6,696,000.0 – 13,392,000.0
	biogas plants of 1 MW/h capacity, units	-	-	372
Chicken dung	biogas yield, m^3/24h	1,249,800.0	822,912.0	1,326,000.0
	electricity generation, kWh a day	1,874,700.0 – 3,749,400.0	1,234,368.0 – 2,468,736.0	1,989,000.0 – 3,978,000.0
	biogas plants of 1 MWel capacity, units	-	-	102
		Calculations based on export substitution assumption		
Corn silage	biogas yield, m^3/24h	11,475,616.4		9,396,000.0
	electricity generation, kWh a day	17,213,424.6 – 34,426,849.2		14,094,000.0 – 28,188,000.0
	biogas plants of 1 MWel capacity, units	-		783

Source: Own calculations.

5. Who pays the bill?

Today the state guarantees electricity producers from biomass a certain level of state guaranteed income for buying electricity at higher prices. Comparing the cost of production of 1 kWh of electricity by three sizes of biogas plants from three different feedstocks with the value of "green tariffs" set for electricity generated from biomass, we estimated the annual level of "support", guaranteed by the state to electricity providers and paid either by final consumers, when the regulated tariffs for electricity are raised or by Oblenergoes, when the wholesale tariffs are raised and regulated ones remain constant (Table 8).

Table 8
Guaranteed level of income under the green tariff

Feedstock	Plant capacity, kWel	Cost of 1 kWel/h generated by the plant, UAH/kWh	Difference between Green tariff and production cost, UAH/kWh	Annual level of income, UAH/year
Silage corn	500	0.52	0.82	3,588,686
	1000	0.49	0.85	7,449,078
	3000	0.49	0.85	22,355,629
Pig and cattle manure	500	0.43	0.91	3,998,984
	1000	0.42	0.92	8,098,469
	3000	0.40	0.94	24,753,214
Chicken dung	500	0.36	0.98	4,291,222
	1000	0.35	0.99	8,667,946
	3000	0.31	1.03	26,992,418

Source: Own calculations.

Comparing the level of the green tariff with the average wholesale price for electricity in October 2009 we can assess the sums to be covered by consumers or electricity distributing companies for each biogas plant (See Table 9).

Table 9
Annual state support for the biogas plant in comparison to the average wholesale price in October 2009

	UAH/year
0.5 MWel	4,059,559.20
1 MWel	8,119,118.40
3 MWel	24,357,355.20

Source: Own calculations.

The wholesale tariff shows the average energy tariff for generated electricity in Ukraine, which is sold to the state company "Energorynok" by different electricity generators and then provided at the averaged prices to Oblenergos. Today the difference of values of "green" tariff and cost of energy from other sources can be "invisible" for consumers, as there is only few plants, operating under the "green" tariff. With the increased number of "green" plants the wholesale energy tariff for Oblenergos will increase and retail tariffs as a consequence too.

Conclusions

With the feedstock available in Ukraine such as pig and cattle manure, chicken dung and corn silage, Ukraine could annually produce up to 5.543 bn m^3 of biogas. Transferring it to electrical energy it means about two times more electricity, namely 11.086 bn kWh, which is about 4-7% of Ukrainian annual electrical energy production.

The newly introduced "green tariffs" can become a stimulus for renewable energy producers. Although according to the law the tariff would be gradually decreased, the next two years is the most appropriate time to invest.

The difference between the current levels of "green tariffs" and retail energy tariffs give investors the opportunity to earn about 1 UAH for each kWh of produced energy. According to our estimation total annual benefits from electricity sale are about 7 bn, 14 bn and 42 bn for plants with the capacities of 0.5, 1 and 3 MWel.

Biogas plants that use corn silage as a feedstock show the highest cost of produced energy. Economies of scale help to reduce costs, making plants from 1 MWel capacities and higher attractive for investors under the assumed conditions.

Biogas production (and electricity generation) of biogas plants of 1 and 3 MWel installed electrical capacities that operate on corn silage under the assumptions of feasible green tariff, constant price level and tariffs and international production technology are profitable.

Biogas production from pig and cattle manure is profitable even at small scale plants of 0.5 MWel. With the capacity increase profitability characteristics become better. Cheaper feedstock is the key factor that distinguishes biogas plants on manure from plants on corn silage and chicken dung in terms of profitability. Biogas plants operating on chicken dung are attractive for investments only starting from 1 MWel installed electrical capacity scale.

Therefore, if cattle and pig manure is used as a feedstock to produce biogas in Ukraine, such production is profitable at all the three levels of electrical capacity analyzed. In case of corn silage or chicken dung as a feedstock biogas plants equal and above 1 MWel electrical capacity bring profits.

With the current feedstock potential Ukraine could substitute about 4-7% of electricity production with the electrical energy from biogas. However this would only be feasible if the Government enforced previously adopted legislative acts regarding the "green" tariff.

References

Biogas Digest. Volume II. Biogas - Application and Product Development. Information and Advisory Service on Appropriate Technology. GTZ.

Biogas-and introduction. FNR 2008.

Comment on the Law of Ukraine No 601-VI "On amending some laws of Ukraine with regard to the introduction of a green tariff" by Justyna Jaroszewska

Decree of the Cabinet of Ministers N 829 from July 29, 2009

Law "On amending some laws of Ukraine with regard to the introduction of a green tariff" from September 25, 2008 N 601-VI

Law of Ukraine "On alternative sources of energy" of 20 February 2003, No 555-IV with amendments introduced by the Law of Ukraine from September 25, 2008 N 601-VI

Law of Ukraine "On amending some laws of Ukraine (with regard to promoting the use of alternative sources of energy)" N 1220-VI from April 1, 2009

Law of Ukraine "On amending some laws of Ukraine with regard to promotion of biofuel production" 1391-VI from 21.05.2009

Law of Ukraine "On electricity" of 16 October 1997, No 575/97

Law of Ukraine "On the alternative types of fuels" from January 14, 2000 N 1391-XIV with amendments introduced by the Law of Ukraine from May 21, 2009 N 1391-VI

NCER Regulation from July 23, 2009 No 857

NCER Regulation from January 15, 2009 No. 25

NCER Regulation from January 22, 2009 No. 32

NCER Regulations from July 16, 2009 No. 828

NERC Regulation from July 16, 2009 No. 838

Order of the Cabinet of Ministers from February 12, 2009 No. 223-p

Order of the Cabinet of Ministers from February 12, 2009 No. 276-p

Order of the Cabinet of Ministers from February 19, 2009 No. 256-p

Order of the Cabinet of Ministers from March 15, 2006 N 145-p

Review of laws and draft laws initiated and considered by the Verkhovna Rada (Parliament) of Ukraine in March 2009 by Justyna Jaroszewska and the Law Firm Sofiya.

T., V. Kryvoruchko, B. Amon, W. Zollitsch, E. Pötsch. Biogas Production from Corn and Clover Grass estimated with the Methane Energy Value System. University of Natural Resources and Applied Life Sciences and 3Federal Research Institute for Agriculture in Alpine Regions

The Order of the Cabinet of Ministers "On ways of feeding in to the electric networks the object of electricity, which produces electricity using alternative sources" from February 19, 2009 N 126

Thyø K. and H. Wenzel (2007). Life Cycle Assessment of Biogas from Corn silage and from Manure. Report, Institute for Product Development.

ВНТП-АПК-02.05, ВНТП-АПК-01.05, ВНТП-АПК-04.05 , ВНТП-АПК-09.06

http://en.wikipedia.org/wiki/Biogas

http://ukrstat.gov.ua/control/uk/localfiles/display/operativ/operativ2009/pr/etgv/etgv_u/elbal_u.html

http://zorg-biogas.com/

ANNEX A

METHODOLOGY AND ANALYSIS

Indicators

Payback period refers to the period of time required for the return on an investment to "repay" the sum of the original investment. Payback period as a tool of analysis is often used because it is easy to apply and easy to understand for most investors. However, it is considered a method of analysis with serious limitations for its use, because it does not properly account for the time value of money, risk, financing or other important considerations such as the opportunity costs. There is no formula to calculate the payback period, excepting the simple case of the initial cash outlay and further constant cash inflows or constant growing cash inflows. Thus, alternative measures of "return" preferred by economists are Net Present Value (NPV) and Internal Rate of Return (IRR).

NPV is defined as the total present value (PV) of a time series of cash flows. It is a standard method for using the time value of money to appraise long-term projects (we consider 15 years for our project). It measures the excess or shortfall of cash flows, in present value terms, once financing charges are met. In general, if NPV value exceeds zero we conclude that our project will generate profit in the future taking into account cash flows discounting by the current discount rate for credits in UAH that we take at the levels of 12% and 28%.

The internal rate of return (IRR) is a rate of return used to measure and compare the profitability of investments. In the context of savings and loans the IRR is also called the effective interest rate or the annualized effective compounded return rate that can be earned on the invested capital. In more familiar terms, the IRR of an investment is the interest rate at which the costs of the investment lead to the benefits of the investment. This means that all gains from the investment are inherent to the time value of money and that the investment has a zero NPV at this interest rate. Therefore, we should compare the received IRR value to the current market interest rate (which is considered as a cost of capital rate) that is currently about 28% in Ukraine. This ensures that investment which IRR exceeds its cost of capital adds value for the company.[48]

Description of costs of the biogas production from corn silage, manure and chicken dung in Ukraine.

Cost of land purchase:

Purchasing land to build a biogas plant is not difficult in Ukraine. According to market information there is a lot of free land that is for sale in Ukraine. Average prices for one hundred square meters (standard measure of land plots in Ukraine is "sotka") that are about 100 km far from oblast centers have been varying in June, 2009 between 50-300 USD.[49] In our calculation we take the price inside given interval of 200 USD, assuming that all accompanying land sale costs are included in this price (legalization costs and payment to realtor). It means that per hectare price is 2000 USD or 15220 UAH (since median exchange rate UAH/USD has been 7.61 in June).Thus, the total cost of land purchase we get by multiplying this price on the land area that is needed to set the equipment for biogas and electricity production.

Cost of electricity consumption:

Tariffs for electricity consumed by enterprises are officially published by National Electricity Regulatory Commission of Ukraine (NERC). Taking an average tariff (without VAT tax) for consumers of 2nd voltage class from the list of energy supplying companies in Ukraine we get

[48] Description of the terms Net Present Value (NPV), Payback Period (PP) and Internal Rate of Return (IRR) are taken from the Online Free Encyclopedia "Wikipedia". For details see:
http://en.wikipedia.org/wiki/Internal_rate_of_return
http://en.wikipedia.org/wiki/Payback_period
http://en.wikipedia.org/wiki/Net_present_value

[49] See, for example, on-line realty sale web-site:
http://realt.ua/Db2/0_Bazad.php?cnt_all=2913&Opr=1&Obj=4&valt=2&srtby=5&pos=0 Please, note that on-line service in land sale in Ukraine gives a lot of propositions only for Kyiv and neighboring regions. However, there are a lot of real-estate agencies which can easily find land everywhere in Ukraine.

0.5846 UAH/kW*hour.[50] Adding VAT tax to this tariff one can get a tariff for electricity that his enterprise or plant must pay for electricity consumed. This tariff equals 0.70152 UAH/kW*hour. Finally, to get the total cost of electricity consumption, we will multiply this tariff on the amount of electricity that a biogas equipment of certain capacity consumes. However, this cost is relevant only for the first year of operation of a biogas plant. In the latter years we will just deduct the amount of electricity consumed by the equipment from the amount of electricity produced. It leads to positive cost-benefit difference.

Cost of heat consumption:

Tariffs for heat energy are calculated from the information given by the Ministry of Housing and Communal services of Ukraine. We take average of all Ukrainian oblasts heat energy tariff for commercial consumers (with VAT tax included).[51] It equals 568.21 UAH/Gkal or, after transformation to a more convenient system of units, 0.4886 UAH/kW*hour. After that we multiply this tariff for the amount of energy needed to heat the premise of a plant, thus receiving the total cost of the plant heat consumption. The cost of heat consumption is effective for the first year of operation only. Next years the plant consumes the heat, that is formed by electricity generation – cogeneration of electricity and heat. This heat is fully consumed by drying process of liquid fertilizers into solid form.

Cost of water consumption:

Similarly to heat consumption cost estimation using the tariffs for water-supply services by basic enterprises in all Ukrainian oblasts given by the Ministry of Housing and Communal services of Ukraine, we get average tariff for water consumption in Ukraine equal to 5.22 UAH/cubic m or UAH/t. Multiplying this tariff by the amount of water consumption by the plant, we can estimate total cost of water consumption. We should also take into account here that after the first year of plant operation, water will appear as a by-product of processing of raw materials (especially, it concerns manure when an excess of water can appear). That is why there is no need to buy additional water for biogas plant operation in the following years that makes cost of water consumption being a one-time (of the first year) only.

Cost of personnel:

To estimate the cost of personnel, firstly, we take the average wage of Ukrainian employees working in agricultural and hunting spheres. It was 1055 UAH/month cumulative for January-April or 1186 UAH/month in April, 2009.[52] This wage is just statistical average in Ukrainian agriculture. Taking into account market reality and companies practice in Ukraine, we will use the wage of 3000 UAH/month in our calculations. Starting from the 2nd year of a biogas plant operation we consider the growth of wage by 10% and put 3300 UAH/ month in the following years. To get the total cost of personnel, one should multiply the number of needed for biogas plant operation employees by given above wage. What is more important is that in our calculations we double the number of employees who are needed to manage the plant (by equipment provider data) since we account for their vacations, sick leave, overtime work, etc.

Cost of a biogas equipment:

We consider German biogas equipment. Costs of biogas equipment include project documentation, construction, supervision and equipment costs. Project documentation cost includes the whole plant design on paper (sketch) for a concrete biogas plant project. Construction cost includes the whole construction work of a biogas plant, including all necessary materials and equipment that are needed for that. After that one engineer from the company that supply the biogas equipment comes to the place of constructed plant and supervise the assembling and start-up of the equipment, its adjustment. Also supervision costs include costs of any number of personnel training that will work on this biogas plant. Finally, we, of course, include costs of equipment to

[50] This number has not changed in 2009, and is given by the state of September, 2009. See http://www.nerc.gov.ua/control/uk/publish/article/main?art_id=82493&cat_id=34446
[51] See http://www.minjkg.gov.ua/index.php?id=1724. Tariffs are given by the state of May 1, 2009.
[52] State Statistics Committee of Ukraine:
http://ukrstat.gov.ua/control/uk/localfiles/display/operativ/operativ2009/qdn/Zarp_ek_p/zpp2009_u.htm
http://ukrstat.gov.ua/control/uk/localfiles/display/operativ/operativ2009/qdn/Zarp_ek_m/zpm2009_u.htm

produce biogas and to generate electricity from obtained biogas then. After that we sum all this costs to receive the total cost of a biogas equipment that, afterwards, we transfer from euros to hryvnas using the median UAH/EUR exchange rate for June, 2009 in Ukraine, which is 10.65.

Cost of the biogas equipment maintenance and repair:

The mainetance cost of equipment equal 0.01 Euro/kWh of the produced electricity. For the plant of 0.5 MWel installed electrical capacity annual maintenance cost will make up 43800 Euro, for 1 MWel – 87600 Euro and for 3 MWel - 262800 Euro.

Cost of raw materials:

Manure and chicken dung cost:

It is a well-known fact that formal market for manure does not exist. But manure should have a value at least because it can affect crop production.[53] Thus, to estimate the value of manure we will look at it as a fertilizer. Manure can be regarded as an excellent fertilizer containing many nutrients including: nitrogen, phosphorus, potassium and many others. However, nitrogen is often the main nutrient of concern for most crops.[54] Therefore, to calculate the value of manure we will equate its nitrogen content with a nitrogen content of an effective fertilizer.[55] The best choice for the fertilizer here is nitroamophoska[56] that is of a balanced composition of three important chemical elements: nitrogen, phosphorus, and potassium – N : P : K =1:1:1. Value calculations are given in the Table below.

Calculation of Potential Prices for Dry Manure in Ukraine

	Nitrogen content, %	Market Price, UAH/t	Price based on nitrogen content, UAH/t
Nitroamophoska	16	3200**	512
Dry Cattle Manure	3.2*	-	102.4
Dry Pig Manure	6*	-	192
Dry Chicken Dung	6.4*	-	204.8

Source: Own calculation based on:
* National Agrarian University;
** EXW price of nitroamophoska, http://www.agron.com.ua.

Finally, to determine total cost of pig or cattle manure, or chicken dung we can apply pragmatic approach of multiplication of a defined quantity of certain raw material to produce set electricity amount by its price that is calculated above. But following market reality and business operators information we put the prices of 35 UAH/t for cattle and pig manure and of 50 UAH/t for chicken dung. We assume that this calculated price consists of the prime (production) cost plus all needed extra charges (like transport costs, for example).

Corn for silage cost:

We focused our assumptions on calculations of production costs of silage corn based on current market prices. In these calculations we consider the total period of silage corn growing to be 12 month, including autumn filed works (tillage, cultivation), early spring fertilizing and the corn transportation to the storages. To estimate the price of silage corn we sum up the costs associated with the workers wages, seeds, fertilizers and fuel purchase, harvest insurance, land

[53] Massey R. and J. Lory (2003). The Value of Manure as a Fertilizer. LPES Updates, University of Missouri.
[54] Ecochem. Manure is an Excellent Fertilizer. Accessed on June 9, 2009 from http://www.ecochem.com/t_manure_fert.html
[55] The same method was applied by Elke Lakemeyer. She states that "one cubic metre liquid manure transform into an average of 4 kg N, that is 2,4 US$ based on the nitrogen content". For details see Lakemeyer E. (2007). Bioenergy production in Ukraine: the competitiveness of crops and other raw materials from agriculture and forestry. Policy paper # AgPP11, IER and German-Ukrainian Policy Dialogue in Agriculture.
[56] Nitroamophoska is considered to be one of the best physiologically neutral fertilizers. It contains main elements of mineral crop fertilization in the kind of water-dissoluble and easily accessible compounds. It can be used in all soils and climatic zones for different crops. We will consider nitroamophoska of the brand 16:16:16 that is one of the most widely spread.

rent and machinery depreciation. Thus, we get production cost. Marking up this cost for producer and seller gains, we get the price of 160 UAH/t for agriholding and 139 UAH/t for the farmer.

Description of benefits from biogas production from corn silage, manure and chicken dung in Ukraine.

Producing biogas in Ukraine we can benefit from selling the electricity by green tariff and also from selling liquid and solid bio-fertilizers that are got as by-products during biogas production.

Benefit from the electricity sale

Adding an electricity generator to other biogas producing equipment in the plant, one can benefit from the Ukrainian policy on stimulation of alternative sources of energy production. Despite the fact that such generator is very costly, selling produced with it electricity by green tariff can bring significant profit. In this paper we overview three scenarios of 0.5 MWel, 1 MWel and 3 MWel of electricity production. To estimate these benefits we just multiply the green tariff of 1.61 UAH/kW*h (with VAT tax included) by the amount (kWh) of received electricity (deducting before this the amount of electricity needed for own consumption).

Benefit from fertilizers sale

As was mentioned above, by-products in the form of liquid and solid bio-fertilizers can be obtained during the process of biogas production. These by products can bring significant profit to the plant. To calculate this profit we multiply the quantity of received fertilizers for a given capacity of a biogas plant by their price. Taking into account undeveloped markets of bio-fertilizers and difficulties with their sale, in our benefits assessments we imply the data of market players – price on the level of 20 Euro/m^3 that equals 213 UAH/m^3. In the end we subtract profit tax from the revenue obtained from bio-fertilizers sale.

Benefit from heat sale

On average heat production by the cogeneration (combined production of electricity and heat) by 20% surpasses electricity production. However, we don't consider any benefits from the heat sale. First reason is that this heat is fully consumed to dry the bio-fertilizer to a solid substance. Furthermore, Ukraine doesn't have a proper legislative environment yet to put into practice efficient heat sale by biogas plants. The current practice shows, that some plants rather deny the income opportunity from the sale of heat. Although in future, heat sale can become a sufficient income source for biogas producers.

ANNEX B

MODEL CALCULATIONS ON ESTIMATION OF PROFITABILITY OF BIOGAS PRODUCTION FROM CORN SILAGE [a]

		year 0	year 1	year 2-14
0.5 MWel				
a	Biogas equipment costs, UAH/year	16,747,125	0	0
b	Other production and maintenance costs, UAH/year	4,566	2,541,567 [b]	2,297,670
			2,311,617	2,067,720
c	Electricity sale benefit by green tariff, UAH/year	0	7,067,112.48	6,643,085.73
d	Profit, UAH/year	-16,751,691	4,525,546	4,345,416
		-16,751,691	4,755,496	4,575,366
e	Payback period (PP), years	3.86		
		3.66		
f	Net Present Value (NPV) when i=12%, UAH	12,211,286		
		13,735,433		
g	Net Present Value (NPV) when i=28%, UAH	-1,581,327		
		-785,991		
h	Internal Rate of Return (IRR), %	25		
		27		
1 MWel				
a	Biogas equipment costs, UAH/year	27,295,950	0	0
b	Other production, operation and maintenance costs, UAH/year	6,849	4,980,407	4,516,140
			4,520,507	4,056,240
c	Electricity sale benefit by green tariff, UAH/year	0	14,134,225	13,356,843
d	Profit, UAH/year	-27,302,799	9,153,818	8,840,703
		-27,302,799	9,613,718	9,300,603
e	Payback period (PP), years	3.09		
		2.94		
f	Net Present Value (NPV) when i=12%, UAH	20,230,018		
		22,688,729		
g	Net Present Value (NPV) when i=28%, UAH	3,519,462		
		5,110,134		
h	Internal Rate of Return (IRR), %	32		
		34		
3 MWel				
a	Biogas equipment costs, UAH/year	71,988,675	0	0
b	Other production, operation and maintenance costs, UAH/year	18,264	14,705,043	13,390,020
			13,325,343	12,010,320
c	Electricity sale benefit by green tariff, UAH/year	0	42,402,675	40,282,541
d	Profit, UAH/year	-72,006,939	27,697,632	26,892,521
		-72,006,939	29,077,332	28,272,221
e	Payback period (PP), years	2.68		
		2.55		
f	Net Present Value (NPV) when i=12%, UAH	72,456,588		
		79,832,722		
g	Net Present Value (NPV) when i=28%, UAH	21,636,136		
		26,408,151		
h	Internal Rate of Return (IRR), %	37		
		39		

Source: Own calculations.

Note:

(a) In these calculations we assume the biogas yield of corn silage on the level 200 m^3/t (since this level is also assumed by equipment provider characteristics that we applied).

(b) Split rows show results for different feedstock prices. The upper one (**grey**) is for agroholding price of silage corn of 160 UAH/t with transportation cost included; the lower one is for farmer price of 139 UAH/t with transportation cost included.

ANNEX C

MODEL CALCULATIONS ON ESTIMATION OF PROFITABILITY OF BIOGAS PRODUCTION FROM PIG AND CATTLE MANURE.

		year 0	year 1	year 2-14
0.5 MWel				
a	Biogas equipment costs, UAH/year	15,570,300	0	0
b	Other production and maintenance costs, UAH/year	7,610	2,067,067	1,823,170
c	Electricity sale benefit by green tariff, UAH/year	0	7,067,113	6,643,086
d	Profit, UAH/year	-15,577,910	5,000,046	4,819,916
e	Payback period (PP), years	3.23		
f	Net Present Value (NPV) when i=12%, UAH	16,530,132		
g	Net Present Value (NPV) when i=28%, UAH	1,233,624		
h	Internal Rate of Return (IRR), %	30%		
1 MWel				
a	Biogas equipment costs, UAH/year	25,794,300	0	0
b	Other production, operation and maintenance costs, UAH/year	9,893	4,000,681	3,567,140
c	Electricity sale benefit by green tariff, UAH/year	0	14,134,225	13,427,514
d	Profit, UAH/year	-25,804,194	10,133,544	9,860,374
e	Payback period (PP), years	2.62		
f	Net Present Value (NPV) when i=12%, UAH	39,795,925		
g	Net Present Value (NPV) when i=28%, UAH	8,513,633		
h	Internal Rate of Return (IRR), %	38%		
3 MWel				
a	Biogas equipment costs, UAH/year	71,509,425	0	0
b	Other production, operation and maintenance costs, UAH/year	18,264	11,673,683	10,543,020
c	Electricity sale benefit by green tariff, UAH/year	0	42,402,675	40,706,568
d	Profit, UAH/year	-71,527,689	30,728,992	30,163,548
e	Payback period (PP), years	2.37		
f	Net Present Value (NPV) when i=12%, UAH	128,906,241		
g	Net Present Value (NPV) when i=28%, UAH	33,241,757		
h	Internal Rate of Return (IRR), %	42%		

Source: Own calculations.

Note: In these calculations we assume the biogas yield from pig and cattle manure on the level 60 m^3/t (since this level is also assumed in equipment provider characteristics that we applied).

ANNEX D

RESULTS OF MODEL CALCULATIONS ON ESTIMATION OF PROFITABILITY OF BIOGAS PRODUCTION FROM CHICKEN DUNG.

		year 0	year 1	year 2-14
0.5 MWel				
a	Biogas equipment costs, UAH/year	18,775,950	0	0
b	Other production and maintenance costs, UAH/year	4,566	1,726,648	1,458,170
c	Electricity sale benefit by green tariff, UAH/year	0	7,067,113	6,586,549
d	Profit, UAH/year	-18,780,516	5,340,464	5,128,379
e	Payback period (PP), years	3.66		
f	Net Present Value (NPV) when i=12%, UAH	15,400,604		
g	Net Present Value (NPV) when i=28%, UAH	-877,125		
h	Internal Rate of Return (IRR), %	27%		
1 MWel				
a	Biogas equipment costs, UAH/year	31,470,750	0	0
b	Other production, operation and maintenance costs, UAH/year	7,610	3,404,134	2,916,340
c	Electricity sale benefit by green tariff, UAH/year	0	14,134,225	13,286,172
d	Profit, UAH/year	-31,478,360	10,730,091	10,369,831
e	Payback period (PP), years	3.04		
f	Net Present Value (NPV) when i=12%, UAH	37,576,288		
g	Net Present Value (NPV) when i=28%, UAH	4,669,583		
h	Internal Rate of Return (IRR), %	33%		
3 MWel				
a	Biogas equipment costs, UAH/year	89,758,200	0	0
b	Other production, operation and maintenance costs, UAH/year	10,958	9,740,043	8,432,220
c	Electricity sale benefit by green tariff, UAH/year	0	42,402,675	40,282,541
d	Profit, UAH/year	-89,769,158	32,662,632	31,850,321
e	Payback period (PP), years	2.82		
f	Net Present Value (NPV) when i=12%, UAH	122,065,406		
g	Net Present Value (NPV) when i=28%, UAH	21,027,253		
h	Internal Rate of Return (IRR), %	35%		

Source: Own calculations.

Note: In these calculations we assume the biogas yield of chicken dung from layers on the level 130 m^3/t (since this level is also built in in equipment provider characteristics that we applied).

ANNEX E

ALTERNATIVE METHOD OF BIOGAS POTENTIAL ESTIMATION (BASED ON MANURE OUTPUT FROM CATTLE AND PIG MANURE AND CHICKEN DUNG).

	Number of animals in agricultural enterprises, thd heads	Dry manure output per head, kg/24h	Crude manure output per head, kg/24h	Total dry manure potential in Ukraine, tons/24h	Total crude manure potential in Ukraine, tons/24h	Biogas output, m3/ton	Total biogas output, m3/24h
Total livestock	*1,720.10*			*7,083.35*	*59,989.80*	*45.00*	*2,699,541.00*
cows	624.30	6.30	55.00	3,933.09	34,336.50		
calves under 1 year	425.20		12.00		5,102.40		
cows of 1-2 years	85.20	3.59	27.00	305.87	2,300.40		
cows from 2 years and older (sired)	85.80	6.30	35.00	540.54	3,003.00		
cows from 2 years and older (unsired)	46.90	6.30	35.00	295.47	1,641.50		
bulls-producers	2.50	5.60	40.00	14.00	100.00		
other cows and bulls	450.20	4.43	30.00	1,994.39	13,506.00		
Total Pigs	*2,730.90*			*1,702.79*	*14,558.31*	*60.00*	*873,498.60*
Main sows	226.70	1.10	15.30	249.37	3,468.51		
Sows that are being checked	92.70	0.88	8.80	81.58	815.76		
Remount piglets over 4 months	135.60	0.80	1.80	108.48	244.08		
Piglets under 2 months	647.40	0.05	0.40	31.08	258.96		
Other pigs	1,628.50	0.76	6.00	1,232.29	9,771.00		
Hens and cocks	*85,720.00*	*0.04*	*0.12*	*3,685.96*	*10,286.40*	*80.00*	*822,912.00*
Total				**12,472.10**	**84,834.51**		**4,395,951.60**

Source: Own calculations based on National Agrarian University, ВНТП-АПК-09.06, Ministry of Agrarian Policy of Ukraine, equipment provider and State Statistics Committee of Ukraine data.

As can be seen from the Table, total manure potential that could be obtained from all livestock of cattle, pigs and hens in Ukraine is about 85 thd tons per 24 hours if to judge by crude matter. From this manure we could produce 4.4 mln m^3 of biogas per 24 hours if to do rough calculations following average biogas normative output per ton of manure.