Биоэнергетическая ассоциация Украины

THE PROSPECTS OF BIOGAS PRODUCTION AND USE IN UKRAINE

Position Paper N4

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Content

Introduction

UABio's Position Paper N4 is a regular document of the planned series of publications on key issues of bioenergy development in Ukraine. In the Paper, the main obstacles hindering the development of biogas technologies in the country and worldwide are identified and analyzed. Ukraine's biogas production potential is exhibited. There are suggested some possible ways to overcome the existing barriers.

Biogas technologies development in EU and in the world

To date, renewable energy sources (RES) take the significant place in the world energy balance. According to the findings of the International Energy Agency[1], 13.1% of the world primary energy in 2010 was produced from renewable energy sources, most of which was biomass - 9.9%. Since 1991, the consumption of energy from renewable energy sources in the EU has doubled and in 2009 was equal to 153 Mtoe/year, or 9% of total EU-27 energy consumption. Energy from biomass amounted to 107.1 million tons of oil equivalent (70% of the whole renewable sources)[2].

Electricity production in the EU in the recent years reached to the level of about 3200-3300 TWh/year. The share of renewable energy sources amounts for about 21% of total production. In the structure of renewable electricity production, hydropower ranks first place (57% of all renewable energy); wind power (21%) and biomass (19%) take second and third places respectively. Renewable energy is expected be provide 34% of total EU electricity consumption in 2020. The production of electricity from biomass (solid biomass, organic waste, biogas) should triple to 300 TWh/year.

One of the most important sectors of renewable energy in the world is the production and use of biogas energy. Leader in the production of biogas can rightly be considered the EU in general and Germany in particular. Total biogas production in the EU-25 in 2010 was 10.9 million tons of oil equivalent (equivalent to 13.5 billion m^3 of natural gas), from which 6.7 million tons of oil equivalent had been made in Germany[3] (Table 1). The increase was 31.3% comparing to 2009.

The total number of biogas plants in Europe is more than 11 thousand units. In 2011, in Germany, according to the National Biogas Association there were launched 1310 new biogas plants. Total number of biogas plants in Germany amounted to 7215 units, while their total installed capacity reached to 2.9 GW. During the year there were produced 19.4 TWh of electricity from biogas, accounting for 3% of the total electricity produced in the country.

[1] Renewables Information. IEA 2010; Europe in figures – Eurostat Yearbook 2010: http://www.iea.org/stats

[2] Renewables Information. IEA, 2010; Eurostat http://epp.eurostat.ec.europa.eu; Solid Biomass Barometer, 2010; EU energy and transport in figures, 2010; AEBIOM Annual Statistical Report , 2011

[3] The state of renewable energies in Europe. 11-th EurObserv'ER Report. 2011
Available at: http://www.eurobserv-er.org/pdf/barobilan11.pdf

Table 1 – Biogas production and energy generation in EU countries in 2010

Country	Biogas production, th t.o.e				Gross biogas and energy production, GWh		
	Biogas from MSW landfills	Sewage water biogas[1]	Other biogas types [2]	Total	Thermal power-station	CHP	Total
Germany	232,5	402,6	6034,5	6669,6	14847,0	1358,0	16205,0
Great Britain	1492,6	258,0	0,0	1750,6	5137,0	575,0	5712,0
Italy	349,6	8,1	149,8	507,5	1451,2	602,9	2054,1
France	255,9	44,2	53,5	353,6	756,0	296,1	1052,1
The Netherlands	36,7	50,2	206,5	293,4	82,0	946,0	1028,0
Czech Republic	29,5	35,9	111,3	176,7	361,0	275,0	636,0
Spain	119,6	12,4	66,7	198,7	536,0	117,0	653,0
Austria	5,1	22,3	144,2	171,6	603,0	45,0	648,0
Poland	43,3	63,3	8,0	114,6	149,3	418,0	567,3
Belgium	41,9	14,6	70,9	127,4	0,0	398,4	398,4
Sweden	35,7	60,7	14,8	111,2	1,0	352,0	353,0
Denmark	8,1	20,1	74,0	102,2	184,0	22,0	206,0
Greece	51,7	15,0	1,0	67,7	190,5	31,4	221,9
Ireland	44,2	9,6	4,6	58,4	75,0	21,0	96,0
Finland	22,7	13,2	4,6	40,4	90,0	11,0	101,0
Slovakia	0,8	9,5	1,8	12,2	51,5	37,8	89,2
Portugal	28,2	1,7	0,8	30,7	7,2	90,2	97,4
Slovenia	7,7	2,8	19,9	30,4	1,0	21,0	22,0
Hungary	2,6	12,3	19,3	34,2	5,9	50,8	56,7
Lithuania	7,9	3,3	2,2	13,3	0,0	55,9	55,9
Luxemburg	0,1	1,2	11,7	13,0	0,0	31,0	31,0
Latvia	2,0	3,0	5,0	10,0	0,0	36,4	36,4
Romania	0,0	0,0	3,0	3,0	0,0	1,0	1,0
Estonia	2,7	1,1	0,0	3,7	0,0	10,2	10,2
Cyprus	0,0	0,0	1,0	1,0	-	-	-
Total in EU	**2801,7**	**1065,0**	**7008,8**	**10875,4**	**24528,2**	**5803,0**	**30331,2**

[1] Municipal and industrial wastewater

[2] Farm type biogas plants, methanization plants an organic part of MSW, centralized biogas plants

In 2011 in European Union 56.7% of biogas was produced in biogas plants processing agricultural waste as raw materials and specially grown plants. About a third of biogas (31.3%) was recovered at landfills. The remaining part (12%) produced at wastewater treatment plants. Thus different European countries have different specialization. Landfill gas plays a major role in the United Kingdom, France, Italy and Spain, while biogas from agricultural waste and plants is dominant in Germany, the Netherlands, the Czech Republic, Austria, Belgium, Denmark and Eastern Europe.

Biogas is mainly used for the production of electricity and/or heat. The dominant part of the utilized biogas energy goes to electricity production. In 2011, the production of electricity from biogas in the EU has increased by 18.4% in comparison with 2010 and reached to 35.9 TWh. During the same period of time, sales of heat produced using biogas, to enterprises and thermal networks increased by 16% to 2.2 million tons of oil equivalent.

In the balance of electricity production from renewable energy sources in the EU[4] the share of electricity from biogas is 4.5%, and in the balance of power production from biomass it equals to 24.4%. According to the official forecast of the European Commission regarding the structure of the electricity production from renewable energy sources in the EU in 2020, the share of electricity from biogas will be about 8%, exceeding the contribution of small hydro, geothermal and solar energy and energy from waste.

A significant proportion of biogas primary energy is consumed for own requirements of biogas plant (heating bioreactors, the drive mechanisms), or simply dissipated as heat into the atmosphere, due to the lack of nearby thermal energy consumers. In this regard, projects for the production of purified biogas (biomethane), followed by injection into the NG network, began rapidly developing in recent years. In 2011 in European Union, according to various sources, there were about 180 plants for biomethane production, 130 of which supplied biomethane into the gas distribution grid, and others used biomethane as a vehicle fuel. Total capacity of biomethane plants was 70,000 Nm^3/h. 87 plants, which produced 55,930 Nm^3/h biomethane, have been operated only in Germany in July 2012. At the same time, another 39 units have being constructed with a view to increase biomethane production to 81,620 Nm^3/h. In Sweden, 7 biomethane plants from the total amount (which was equal to 47 units) were supplying biomethane into the gas network, the other were producing motor fuels for transport; in Switzerland 7 and 15 respectively; and in the Netherlands all 13 units provided biomethane supply into natural gas distributing grid. The total production of biomethane in 8 EU countries in 2010-2011 amounted to about 0.5 billion m^3 per year[5].

In addition, there developed projects of biogas plants construction in the vicinity of heat consumers or the creation of such heat consumers near biogas plants. This has enabled better use of the produced biogas energy during the periods and at the locations of maximum full use of the produced heat energy.

Large volumes of biogas and biomethane were the result of specially grown energy crops additional use as a substrate (mainly maize silage). For example, in Germany for this purpose there has been involved about 1 million hectares, accounting for 8.3% of the total area of arable land (more than 12 million hectares).

Roadmap for the biogas production in the EU[6] shows the possibility of biogas production in the EU-27 in 2020 at an amount equivalent to 29.43 million t.o.e. (equivalent to 36.29 billion m^3 of natural gas). It's enough to use 35 % of waste manure from animals farm and energy crops grow at 5% of agricultural land. Meanwhile, approximately 3/5 of the biogas volume will be produced from energy crops, 1/5 from manure, and 1/5 from other wastes and by-products of industry and agriculture. According to analysts, the biogas market will continue developing rapidly, replacing other energy sources in total energy balance of the countries.

[4] Renewable Energy Road Map. Renewable energies in the 21st century: building a more sustainable future. COM(2006) 848 final, Brussels, 10.01.2007 : http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2006:0848:FIN:EN:PDF

[5] Overview of biomethane markets and regulations in partner countries. March 2012. Fraunhofer Umsicht: http://www.greengasgrids.eu/sites/default/files/files/120529_D2_2_Overview_of_biomethane_markets_rev1.pdf

[6] A biogas road map for Europe / AEBIOM – European Biomass Assotiation, October, 2009 Available at: http://www.aebiom.org/IMG/pdf/Brochure_BiogasRoadmap_WEB.pdf

Biogas: definition, main raw material types

Biogas is a combustible gas produced by anaerobic methane fermentation of biomass and consisting mainly of methane (55 ... 75%), carbon dioxide (25 ... 45%) and impurities of hydrogen sulphide, ammonia, nitrogen oxides and other (less than 1%).

Biomass decomposition occurs as a result of chemical-physical processes and symbiotic vital activity of mainly three groups of bacteria, meanwhile the products of each bacteria metabolism are food products of others in a certain sequence. The first group is the hydrolytic bacteria, the second is an acid-, and the third is methane-producing bacteria.

Organic agro-industrial or domestic waste as well as plant raw materials - corn silage, grass silage, cereals grain and silage can be used as raw material for the biogas production. The most suitable agro-industrial complex (AIC) waste streams for the production of biogas are:

- Pig and cattle manure, poultry litter;
- Vegetable tops;
- Unconditioned grain, vegetables, sugar beet and corn harvest;
- Cake and molasses;
- Grain stillage;
- Shorts, small grains;
- Beer grain, malt sprout and protein residues;
- Residues of starch and treacle production;
- Fruit and vegetable peels and residuals;
- Whey and other milk processing residues.

The number of substrates / wastes used in the biogas production at one biogas plant, may vary from one to ten or more. Depending on the types and kinds of used substrates there exist different options of biogas plants technological schemes. In the case of several substrates with different properties, such as liquid and solid wastes, those accumulation, preliminary processing (crushing, bio-activation, heating, homogenization or other physico-chemical treatment) is carried out separately, then substrates are either blended before being fed into bioreactors, or supply by separate streams. Use of preparation in some cases allows for increasing the speed and degree of decomposition material in bioreactors, and hence the total biogas yield.

Biogas projects in the agricultural sector can be organized in the following ways:

- biogas production based on the waste from a single enterprise (for example, farm animal manure, press of sugar factory, distillery grains), with one type of waste to be dominant;
- biogas production based on waste generated by enterprises, linking the project to a single enterprise or separately located centralized biogas plant;
- biogas production using mainly energy crops in separate biogas plants locations

Biogas projects in the housing sector may be organized as follows:

- biogas production from organic part of municipal solid waste collected by one or more utilities;
- biogas production from sewage sludge of wastewater treatment plants;
- biogas collection at municipal solid waste landfills and dumpsites.

The most common ways of biogas energy use are the following:

- combustion by gas reciprocating engine in the CHP, with the production of electricity and heat (or cold), or production of electric power only;
- direct combustion in boilers, furnaces and other process equipment for thermal energy generation (can be used for municipal / industrial heating, cooking, feeding, etc.);
- injecting into natural gas network after refinement of ballast gases; as a result of treatment, an analogue of the natural gas (biomethane) is obtained with 96 ... 98% methane content;
- use as motor vehicle fuel after deep purification and compression.

All of these methods are used in the world to some extent, but electricity production from biogas in CHP is the dominant one, including through widespread mechanism of stimulation due to the "green" tariff. Recently in the world practice there is observed a rapid growth of biogas projects aimed at the biomethane production and injection into the natural gas distributing network.

Biogas production technologies

The main structural elements of the scheme of a typical biogas plant are:

- The system of substrates receiving and preparation
- The transportation system of substrates within the facility
- Bioreactors (fermenters) with a mixing system
- System of bioreactors heating
- Removal system and biogas refinement from hydrogen sulfide impurities and moisture
- The storage capacity of the digested mass and biogas
- The system of software control and technological processes automation

Biogas plants flow charts are different, depending on the type and number of processed substrates, the type and quality of the final target products, from "know-how" use option of the technological solutions supplier, and other factors. The most common by far is a single-stage fermentation schemes of several substrates types digestion, one of which is the manure. A typical scheme of biogas plant is shown in Fig. 1.

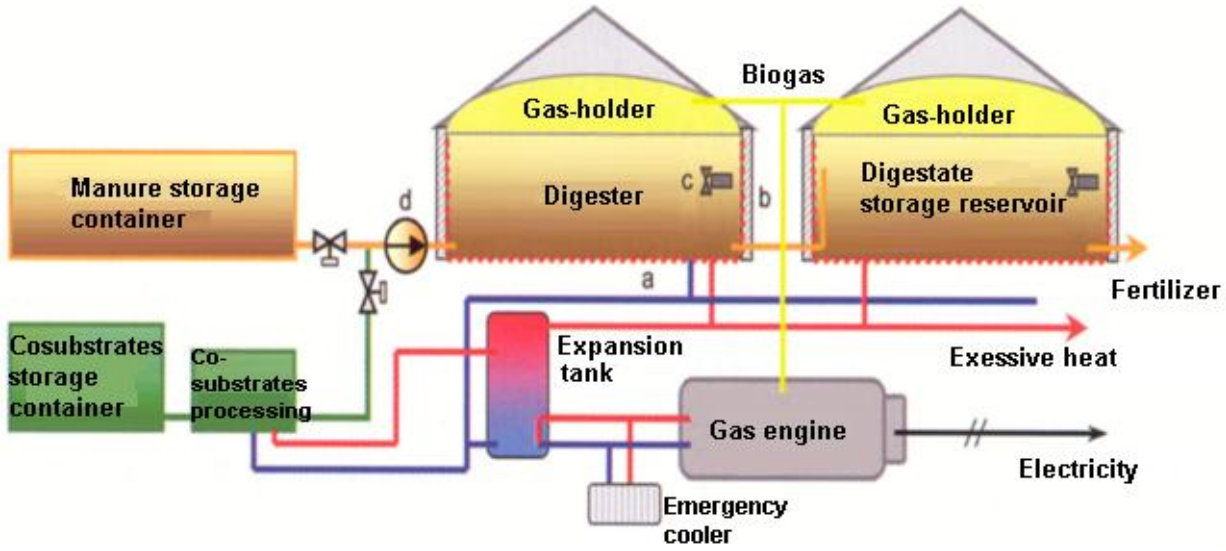

Figure. 1 – Typical scheme of single-stage biogas plant for co-digestion of manure and additional raw materials with mini-CHP operating at biogas

With the development of biogas technology the used schemes are getting more complicated and transform into two-or three-stage ones, which in some cases justified by the need for effective technological processing of substrates certain types and increase the overall efficiency of the bioreactors effective volume.

In case of electricity generation CHP is one of the major additional units based on the internal combustion engine and generator with the connection to the public or a local power grid. Bio-methane production requires biogas upgrading from carbon dioxide, hydrogen sulphide, water vapor and other components. Tested and the most commonly used biogas upgrading technologies are water absorption, adsorption on the media under pressure, chemical precipitation and membrane separation.

The energy efficiency of biogas plants operation much depends on the chosen technology, materials and structure of major facilities, as well as from climatic conditions in the region of their location. The average energy consumption for heating bioreactors in temperate climatic zone (corresponding to the conditions of Ukraine) is 15-30% of the total produced biogas energy (gross). Overall energy efficiency of biogas complex with CHP amounts to 75-80% average. In the situation where heat utilization from cogeneration plant producing electricity is impossible (a common situation is due to lack of heat consumers), it is diverted into the atmosphere. In this case, the energy efficiency of biogas CHP is only 35% of the total biogas energy potential. The average energy efficiency of the bio-methane production plant is 65%. Even with the energy loss during transportation and subsequent burning of biomethane, the energy efficiency of such projects is higher than in the case of electricity production.

Key performance indicators of biogas plants operation can vary widely, which is largely dependent upon the used substrates, operating practices, goals and objectives of each installation. The performance characteristics of the number of biogas plants in Germany are given in Table 2.

Table 2 – Performance characteristics of 61 biogas plants in Germany[7]

Parameter	Unit	Value		
		average	min	max
Organic matter load	Kg VS/m^3/day	3,0	1,1	9,9
Retention time	day	101	29	289
Organic substances decomposition degree	%	76	59	89
Specific CH_4 yield per reactor volume unit	$м^3CH_4/м^3$/day	1,1	0,3	3,2
Specific CH_4 yield per ton of the substrate	$м^3CH_4$/t	86	28	141
Specific CH_4 yield per ton of the applied VS	$м^3CH_4$/tVS	371	224	464

Fermented mass (digestate) is a valuable material as fertilizer for soil quality conditioning, excelling unfermented materials in this respect, and a little bit inferior to mineral fertilizer or compost. The value of this mass is determined by the nutrients presence. As a rule, digested mass is divided into liquid and solid fractions using the separator. The liquid fraction is sent to a lagoon where it is accumulated before the soil application. Dehydrated solid fraction can be used as fertilizer, and after further drying and packaging, suitable for long-term storage and transportation over the long distances.

For the fermentation of organic solid waste like kitchen residues, wastes of food industry and green gardening waste a variety of methods can be used. The most common is "wet" method, in which the analogues of traditional agricultural biogas plants are applied. In this case, the MSW can be digested separately or as an additional substrate. The methods of solid waste "dry" digestion in the columns or containers have also gained certain spread.

For MSW digestion in bioreactors becomes possible it is necessary to provide solid waste sorting or separate collection. An alternative to the managed biogas production from organic fraction of solid waste is collection and, in the case of economic feasibility, the energy utilization of biogas at MSW landfills and dumpsites.

The advantages of biogas technologies

The production and use of biogas energy has a number of sound advantages proven by global practice, namely:

- **Renewable energy source**. Biogas is produced using renewable biomass.
- **A wide range of raw materials** used for biogas production allows constructing biogas plants practically in all the areas of agricultural production concentration and technology-related industries.
- **Universality of biogas energy utilization ways** for the production of electricity and / or heat at the place of its formation, and at any object connected to the natural gas distribution network (in the case of supply of biomethane), and also use as a motor fuel**.**

[7] Biogas-Messprogramm II. 61 Biogasanlagen im Vergleich, FHR. 2009

- **The stability of electricity production from biogas during the year** to cover the peak load of power grid, especially in view of unstable renewable energy sources operation such as solar and wind power stations.
- **Competitive energy use of arable land** compared to the production of liquid fuels (bioethanol and biodiesel). It is proven[8] that in the case of biogas production from energy maize hybrids, net energy production from 1 ha of arable land is about 2 (in the case of electricity production) to 4 (in the case of CHP) time higher than in the production of bioethanol or biodiesel (Figure. 2).

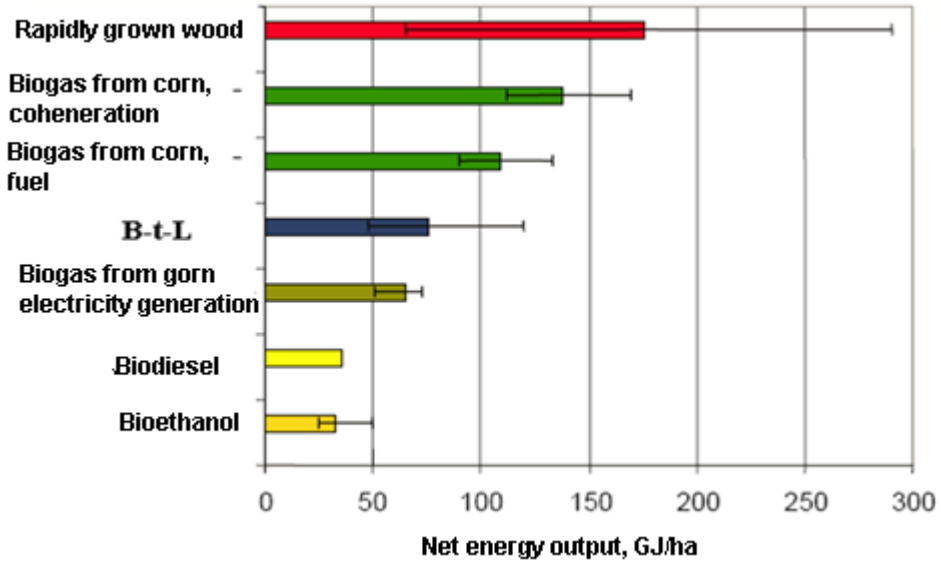

Figure 2 – Net energy production while energy use of arable lands for the different types of biomass alternative fuels

- **Creating jobs** through the marketing chain formation from biomass suppliers to energy facilities operating personnel. In Germany, the bioenergy sector is leading by the number of jobs created (122 thousand jobs, as of 3/2011) among other renewable energy sectors[9].
- **Reduce the negative environmental impacts** by waste recycling and neutralization through controlled fermentation in biogas reactors or biogas collection from existing landfills. Biogas technology is one of the most efficient ways of organic waste neutralization. Projects for biogas production promote also greenhouse gas emissions redaction.
- **Agronomy effect** of fermented mass in biogas reactors in agricultural fields application results in the soil structure improvement, regeneration and amelioration of soil fertility through nutrient application of organic nature. The development of organic fertilizer market, including recycled mass within biogas reactors in the long term will contribute to the development of the market environment-friendly agricultural products in Ukraine and competitiveness to the same market in the EU.

[8] State Institute of Agricultural Engineering and Bioenergy, Universitat Hohenhaim. Germany, 2009
[9] Biogas production and use in Ukraine // Board on biogas issues / Biogasrat e.V., May, 2012

Biogas production experience, the status of biogas technology development in Ukraine

In Ukraine, there are few examples of biogas technologies implementation. The first one among active full-scale biogas plants on animal waste, was built in 1993 on a pig farm "Zaporizhstal". After that, biogas plants of companies "Agro-Oven", "Elite", "Ukrainian Milk Company" have been launched. As of 2012 on the basis of agricultural enterprises in Ukraine there operated four biogas plants (Table 3).

Table 3 - The existing biogas plants in Ukraine [10]

Enterprise	Start-up year	Livestock population	Raw materials types	Raw material volume, t/day	Digesters volume, $м^3$	Installed power capacity, kW	Technology supplier
Pig farm "Zaporizhstal", Zaporizzhya	1993	8000-12000	Pig manure	20…22	595	-	Bigadan Ltd", Denmark
Pig farm of corporation "Agro-Oven", Elenovka village, Dnipropetrovsk region	2003	15000	Pig manure, fat from poultry slaughter	80	2 x 1000	180	BTG, the Netherlands
Agricultural company «Elita», Teresino village, Kiev region.	2009	1000	Manure (90% cattle+10% pigs)	60	1500	250	LIPP, Germany
Cattle farm of "Ukrainian dairy company", Velykyi Krupil village, Kiev region	2009	4000 + 2000	Cattle manure, maize silage (planned)	400	3 x 2400 + 1000	625 + 330	Zorg, Ukraine

The biogas plant at "Zaporizhstal" pig farm has been implemented for the purpose of liquid waste treatment and reducing of energy consumption; to date, energy (heat) biogas utilization is realized for the pig factory own needs. On the pig farm of corporation "Agro-Oven" electricity produced by biogas plant is consumed for installation and enterprise own needs; meanwhile cogeneration unit is not connected to a power grid.

Operation of biogas plant belonging to "Elite" company was suspended in 2011 due to the unprofitability while the absence of the "green" tariff. The only biogas plant connected to the electricity grid by far is biogas plant at the cattle farm of "Ukrainian dairy company." The company has been allowed to supply and sale of electricity generated at the special tariff (lower than the market rate on the grid electricity for industries). The company planned to increase capacity to 1.0 MWe through the use of additional plant substrates (presumably corn silage).

[10] «SEC «Biomass» data

According to SAEE information there exist biogas plant in Khmelnytsky (village Mokiïvtsi, "Spetsgazremtehnologiya" ltd) and Lviv regions (village Batyatichi, "West -Ukrainian gas technologies" ltd), set into operation in February 2011 with capacity of 1 MW each, but reliable data on their operation is absent.

In September 2011, the construction of biogas plant on the basis of a pig farm has started at village Kopanky, Kalush district, Ivano-Frankivsk region. The enterprise and the biogas plant owner is a Danish company «Danosha Ltd.». Biogas plant capacity was to be 1,064 kWe. Depending on the conditions of produced energy realization, there was supposed to digest pig manure separately (in the absence of "green" tariff) or with the addition of a green plant matter (in the case of adoption of green tariff for biogas).

In 2012, "Mironovskiy Hleboproduct" has started the construction of a biogas plant at the poultry farm "Orel-Leader" in the Dnipropetrovsk region. Ambitious plans to implement a biogas program of thirty biogas plants had been claimed by the company "Ukrlandfarming."

In 2012 agricultural holding company Astarta-Kiev, announced the biogas plant construction at a Globinsky sugar factory (Poltava region) by the EBRD loan of up to 12 million USD for 7 years term. The processing capacity will be more than 120 thousand tons of sugar beet cake per year, which will produce about 14.4 million m^3 of biogas and thus to halve the natural gas volume consumed by the company in the process of sugar production.

Thus, the implementation of biogas technologies remains the stuff of agribusiness leaders, which have their own resources to work in a weak financial market and a lack of investment.

A few examples of biogas projects exist on municipal solid waste landfills in the cities of Yalta, Alushta, Lviv, Mariupol, Kremenchug, Lugansk, Kiev (Table 4), and Bortnychi wastewater treatment plant (Kiev).

Table 4 – The current system of biogas collection and utilization at MSW landfills

Landfill	Disposed waste amount, mln t	Landfill area, ha	Landfill operation period	Start of LFG recovery	Utilization technology
Alushta	1,0	3,2	1960-	2008	Flare installation HOFGAS-Ready 500
Yalta	1,3	5,0	1973-2010	2008	Flare installation HOFGAS-Ready 800
Lviv	4,0	26	1957-	2009	Flare installation HOFGAS-Ready 2000
Mariupol	2,5	14	1967-2009	2010	Flare installation HOFGAS-Ready 800, Internal combustion engine 170 kW
Krementchug	2,8	15	1965-		Flare installation Haase
Lugansk	2,0	11,6	1979-2010	2011	Flare installation Biogas Ltd, UK, 600 m^3/h
Zaporizzhya	3,2 (from 1974)	11	1952-	2011	Flare installation Haase
Vinnytsia	3,0	10	1980-	2012	Flare installation Haase
Kyiv	10	36	1986-	2012	Internal combustion engine TEDOM 5x177 kW

The project at the Kiev landfill number 5, implemented by LNK is currently the most successful Ukrainian LFG project. At the landfill there operates a line of five biogas engines of the

company TEDOM with installed capacity of 177 kW each. In 2012, there have been produced, delivered to the network and sold at economically reasonable tariff (determined by NERC), 3.26 GWh of electricity.

The company is expanding the project capacity – the commissioning of gas reciprocating engine produced by GE Jenbacher with power capacity of 1063 kW is scheduled in July - August 2013. In addition, the company LNK officially puts into operation gas reciprocating engine of GE Jenbacher manufacturing with capacity of 1063 kW at the landfill Boryspil in June 2013.

The potential of biogas production in Ukraine

Ukraine's agricultural sector producing large amounts of organic waste, potentially has the resources for biogas generation, which is able to replace the 2.6 billion m^3 of NG per year. With the further development of agriculture and the wide use of green material (silage, grass), this potential can be extended according to various estimates from 7.7[11] to 18[12] billion m^3 NG per year. In the first case it is supposed to use 6% of arable land (50% abandoned land) in Ukraine for growing corn silage for biogas with a conservative yield of 30 t/ha. The share of biogas from maize silage will contribute 53.0% of the total potential; biogas from the by-products and crop residues - 5.7%; biogas from by-products and waste of the food processing industry - 5.3%; and biogas from the animal manure waste - 36%. The second option with a higher forecast involves the use of 7.9 million hectares of land available for growing maize for biogas considering increased productivity.

Table 5 shows the potential for biogas production at existing agriculture enterprises of Ukraine and with the cultivation maize silage for biogas production at 50% of free arable land (with a yield of 40 tons green mass per 1 ha and biogas output 180 m3/t).

Table 5 - The potential of biogas production in a number of agricultural industries of Ukraine

Type of activity	Total number of Ukrainian enterprises	Major production volume	Total volume of the major waste	Biogas production potential from the total volume of the major waste	Economically feasible potential share
		th t / heads	thousand tons	mln m^3/year	At the biogas plant with mini-CHP from 0.1 MWe
In Ukraine total	11667	-	39 727	9 543	54%
Sugar mills	60	1 546.0	23 263.5	975.5	46%
Breweries	51	3 100.0	1 016.8	121.8	10%
Distilleries	58	204.7	2 705.0	116.8	13%
Cattle farms	5079	1 526.4	15 431.6	385.8	97%
Pig farms	5634	3 625.2	5 656.7	160.3	30%
Poultry factories	785	110 561.3	4 721.5	377.7	68%
Maize silage	At 50% of free lands	41 140.4	-	7 405.5	-

[11] Georgii Geletukha, Petro Kucheruk, Yuri Matveev, Tetiana Khodakivska. Biogas production perspectives in Ukraine. Renewable energy", №3, 2011, p.73-77.
[12] Biogas production and use in Ukraine // Board on biogas issues / Biogasrat e.V., May, 2012

The potential volume of biogas market in Ukraine can be assimilated within 10-20 years (until 2030). A necessary prerequisite of these projects in the first phase is the introduction of economically feasible green tariff for electricity from biogas. To implement effective biogas-to-energy projects it is important to stimulate the electricity production from biogas derived not only from biomass waste, but also from specially grown plant materials. In parallel with the electricity generation in Ukraine it is appropriate to implement biomethane production for direct replacement of natural gas, or more efficient energy utilization of biogas for electricity and heat.

In general, biogas market in Ukraine can be considered as forward-looking, with a fairly wide awareness of the participants, awaiting signals from the government. Such signals may initially be putting in force of the legally guaranteed value of "green" tariff for electricity from biogas without restricting the types of equipment or raw materials, other types of real legislative support and regulatory support.

Incentives and barriers to the development of biogas production in Ukraine and suggestions to overcome those barriers

A proven and effective mechanisms to encourage the development of renewable energy in the world is the use of fixed "green" tariffs for electricity produced from renewable energy sources. Green tariff for electricity produced from biogas which is guaranteed by law in Ukraine is valid only from April 2013, and its value is 0,1239 euro/kWh (by a factor of 2.3).

A detailed analysis of the active Ukrainian laws in the field of renewable energy, including those related to the production of biogas, identified key barriers and solutions to overcome these barriers are given in a UABio's Position Papers number 2 and number 3[13].

Five main regulatory barriers to the development of energy production from biomass, particularly from biogas, and suggestions for overcoming those by amending the Law of Ukraine № 5485-VI, had been defined, in particular:

Barrier 1: Unreasonably low coefficient of "green" tariff for electricity from biogas.

UABio's suggestion for overcoming the barrier:

Set the green tariff ratio for electricity produced from biogas at the level of **3.0** for biogas from waste and agricultural products, and **2.7** for all other types of biogas.

Barrier 2: Incorrect definition of the term "biomass"

UABio's suggestion for overcoming the barrier:

Adjust the term "biomass" as follows:

*"At this law biomass is biologically renewable material of organic origin that is biodegradable (**products, waste and residues** of forestry and agriculture (crop and livestock), fisheries and*

[13] http://www.uabio.org/ru/activity/uabio-analytics

technologically related industries), and the component of industrial or domestic waste which is capable of biodegradation."

Barrier 3: Unreasonable demands on the share of the local part of the equipment, materials and services in the total cost of projects

UABio's suggestion for overcoming the barrier:

Revoke any claim by the share of local content for projects applying for the "green" tariff for electricity from biomass and biogas.

Barrier 4: Terminology errors in the main equipment elements description for electric power facilities that use biogas energy

UABio's suggestion for overcoming the barrier:

To correct the errors of the Law #5485-VI we consider it is necessary to extend the law of the table with the elements description of the local component for electric power facilities using biomass and biogas.

These proposals are relevant if lawmakers do not take the previous sentence to disclaim any demand for local part.

Barrier 5: The discriminatory approach to biogas plants, which had been put into operation before 01.04.2013.

UABio's suggestion for overcoming the barrier:

The provisions of the Law should be amended so that the installations that produce electricity from biogas and had been put into operation before 31.03.2013 , could get the "green" tariff along with plants put into operation from 01.04. 2013 to 31.12.2014.

Lack of regulatory framework. In addition to legislative barriers, there also exists the problem of the lack of a modern regulatory construction documents (State Construction Norms) for the design and operation of biogas plants and biogas collection systems at landfills. In this case, the project owners and design organization faced with the need to develop Technical Specifications for the every implemented biogas plant, and government construction regulation agencies are constrained to apply the subjective approach to the building permits issuance, because of the lack of regulatory framework for such projects evaluation. All of this leads to projects launch delays, and to excessive cost for the project owners. Therefore, it is important to initiate the necessary regulatory documentation development in the field of biogas projects with leading experts and specialized organizations involvement.

The complexity of tax exemptions application for the import of bioenergy equipment. Another mechanism to stimulate biogas projects implementation are legally stipulated preferences, such as the exemption from VAT and customs duties. Thereby the current Customs Code of Ukraine (Chapter 42, Article 282, paragraph 14, item 16) provides the exemption from tax duty equipment running on renewable energy sources, equipment and materials for the production of alternative fuels or energy production from renewable energy sources. The acquisition of this equipment and materials will also be exempted from paying VAT on the basis of the Tax Code of

Ukraine, paragraph 197.16.1. List of equipment and components, and materials that can take advantage of the preferences set by CMU resolution # 444-2008-p (current version from 20.12.2012). We believe that the present form of benefits obtaining procedure is opaque and unpredictable, and therefore has the discriminating character regarding the idea of RES projects implementation promoting with evidence of subjective reasoned decision on the individual items inclusion of to the list. As one of the examples there could be highlighted the freeze of already started biogas plant construction at pig farm on the Ukrainian-Danish company "Danosha" in Ivano-Frankivsk region, which was unable to import duty-free equipment into Ukraine.

Lack of Ukrainian biogas projects trust fund. A backward interest in biogas technology as an independent energy sector of Ukraine, insufficient funding for research, and most important, the lack of pilot projects funding on biogas plants construction do not allow Ukrainian manufacturer to compete at this stage with foreign biogas technologies suppliers . At the same time, funding the complete cycle of creating the most relevant and cost-effective pilot biogas projects by Ukrainian production with subsequent replication will allow in the future to involve manufacturing facilities in the various industries of Ukraine.

The absence of an active program for the sector. An important signal from the state will also be involvement of the program approach to biogas technologies development with specific objectives, funding sources and timelines. The concept of such a program is actually approved as a national project "Energy of Biogas" (see below), but has not yet found the proper development, i.e. due to the above mentioned barriers. We believe that enhanced of the national project development, along with overcoming these barriers will provide the necessary impulse for the development of biogas technology in Ukraine and attract investment into biogas industry.

The concept of the national project "Energy from Biogas"

Given the importance of biogas technologies development, i.e. the contribution to energy independence, natural gas substitution, decentralization of energy production, environmental improvement, development of agriculture and creation of new jobs, we consider to be appropriate the support of initiation and implementation of the national project "Energy from Biogas". Brief description of the project is given in Table 6.

Table 6 - The national project "Energy from Biogas"

Project essence	• The implementation of biogas plants and mini-cogeneration plants using biogas with total capacity of 1700 MW heat + 1,500 MW of power; • Production of bio-methane and supply into NG pipelines up to 5 billion m^3 per year.
Strategic goals	• Energy independence of Ukraine; • Production of biomethane as a substitute for natural gas; • The substitution of natural gas consumption - up to 1 billion m^3 per year until 2020, and in the long term - up to 8 billion m^3 per year (up to 2030); • Environmental security of Ukraine;

	• Increase the profitability of agriculture in Ukraine. • Improvement and stabilization of soil fertility - the contribution to the "organic farming" project realization
Programme liability	• The program of environmental reforms in 2010-2014.; • Law of Ukraine "On the main provisions of national agricultural policy for the period up to 2015"; • «The Energy Strategy of Ukraine till 2030"; • The decision of the NSDC of Ukraine.
The economic feasibility	• Replacement of the problematic imported natural gas with biogas and biomethane; • Coverage of the peak in energy consumption; • Obtaining an environmentally friendly biological fertilizers; • Development of the infrastructure of the local economy; • Improving the investment climate in the country; • 7-8 years payback period on some projects in the form of public-private partnership while implementing reasonable green tariff. • Diversification of agricultural production (growing range of commercial products - fertilizer, vitamins, heat, electricity, quotas on greenhouse gases ...)
Social benefits	• Environmental situation improvement; • Creation of new jobs - up to 15 thousand • Self- provision of energy and fertilizers
Implementation period	5-15 years
Investment volume	About 30 billion UAH

Taking into account technical and economic feasibility, as well as the current structure and size of agricultural enterprises in Ukraine (cattle and pig farms, poultry farms, sugar mills, distilleries, breweries), biogas plants market numbers about 1,600 plants with CHP capacity starting from 100 kWe. The total installed capacity of biogas plants could be around 820 MW of power and 1100 MW of heat. Using plant material (presumably silage corn) jointly with manure waste of livestock enterprises is considered to be appropriate, which is justified both in technological and economic terms. The proportion of silage is offered to use at no less than one third of the weight of manure waste. Corn silage use by sugar refineries is based on expediency of the biogas plant operation throughout the year, not just the sugar-making season, when the waste is generated. With the further development of the agro-industrial complex of Ukraine, the total production capacity increase and consolidation of separate production capacities, the potential biogas plant market it is expected to increase by 1.5-2 times.

We consider it is appropriate to cope with 9% in the short term (until 2020) and 51% in the medium term (until 2030) of economically viable market of biogas plants. Therefore total annual output of electric power can reach 0.4484 billion kWh in 2020 and 2,538 billion kWh in 2030. With an overall investment of 15 billion UAH into more than 800 biogas plants of various capacities until

2030, the volume of produced biogas will reach 1.65 billion m^3 per year (1.2 million tons of coal equivalent) (Table 7).

Table 7 - The concept of biogas plants in agriculture and food processing industry by 2030[14]

Power range	Number of plants	Biogas total production	Total installed electrical capacity	Total installed heat capacity	Annual net power production	Annual net heat production	CO_{2eq} emission reduction	Invest-ments	New jobs creation	Land area for the corn
MW_{el}	units	mln m^3/hour	MW_{el}	MW_{heat}	mln kWh	mln Gcal	mln t/year	mln UAH	units	th ha
2020										
0.1-0.5	123	93.3	23.6	31.1	166.7	0.147	0.5	1 103.3	738	9.1
0.5-1.0	12	31.3	7.9	10.4	56.0	0.049	0.2	291.3	99	2.9
1.0-5.0	5	53.0	13.4	17.6	76.6	0.067	0.2	422.3	41	4.6
>5.0	3	114.7	29.0	38.2	149.1	0.131	0.3	828.4	39	10.6
Total	**143**	**292.3**	**74.0**	**97.3**	**448.4**	**0.395**	**1.2**	**2 645.3**	**917**	**27.2**
2030										
0.1-0.5	696	528.0	133.6	175.8	943.7	0.831	2.6	6 224.8	4 178	51.6
0.5-1.0	70	177.3	44.9	59.0	316.9	0.279	1.0	1 648.9	562	16.5
1.0-5.0	29	299.9	75.9	99.8	433.6	0.382	1.0	2 390.4	232	26.1
>5.0	16	649.1	164.3	216.1	843.9	0.743	1.4	4 688.7	220	59.9
Total	**811**	**1654.4**	**418.6**	**550.8**	**2 538.0**	**2.234**	**6.0**	**14 972.8**	**5 193**	**154.1**

Thus about 2/3 of biogas is to be produced from corn silage, and 1/3 volume - from waste. Growth of the required volume of corn silage will require 0.15 million hectares of arable land, accounting for only 0.5% of the total area, or 4.3% of the area of the available arable land (as of 2011). The potential of using waste heat from the CHP in 2020 will amount to 0.395 million Gcal; in 2030 - 2.23 million Gcal. In order to develop this potential, not only electricity use should be stimulated but also heat from biogas; and a combined production of electricity and heat from biogas or biomethane in places with the most full of useful energy recovery should be carried out in prospect. The number of new jobs by 2030, both at direct and related activities will be about 5,200 units; greenhouse gas emissions reducing - about 6 million tons $CO_{2eq/year}$.

Outcomes

- Biogas production in the world in general and the EU in particular, is at the stage of rapid growth with the trend towards intensification of existing biogas production technologies, as well as search for new raw materials and technologies for its processing into biogas, more effective use of biogas energy. In 2010 in EU there was produced 13.5 billion m^3 of biogas in terms of natural gas equivalent, and this figure is supposed to increase later on.

[14] «SEC «Biomass» data

- The development of biogas technologies in Ukraine will allow future replacing of 2.6 - 18 billion m^3 natural gas per year. Besides, biogas technologies development will make a significant contribution to energy independence, will form an alternative gas fuel resource, and provide the ability to cover peak loads in power grid, and also facilitate creation of new jobs and local economy progress.
- For strong build-up of energy production from biogas it is necessary to create conditions for this type of business development that would attract both domestic and foreign investment, allows use of advanced technologies from abroad, as well as contribute to the domestic counterparts development on the basis of innovative solutions.
- While solving the energy problem by stimulating the production of electricity from biogas, biomethane production for injection into the gas distribution network and for fueling vehicles, the government increases an environmental security level in the territory of Ukraine, because waste from agriculture and public utilities and also food processing industries pose a threat to public health, soil, air and groundwater. Biogas technology is one of the main and most efficient ways of organic waste treatment.
- Organic waste processed by anaerobic methods is a valuable organic fertilizer that can increase the quality of soil - one of the most valuable resources of the state, as well as improve the competitiveness of agricultural products.
- Construction of biogas plants and infrastructure with a gradual transition to the equipment of local production will further stimulate the Ukrainian economy. The expected investment in this sector could be more than 30 billion UAH in the medium term

Advantages of biogas technology are out of the doubts, as evidenced by their rapid development worldwide. Similarly, such technology, according to the authors' position, should be implemented in Ukraine. For this purpose it is necessary to remove the barriers at the legislative level, in permits and approval documentation, to make the mechanism for obtaining tax relief on the import of the equipment for renewable energy projects clear and unambiguous, to facilitate the development of the national project "Energy from Biogas". Biogas and bio-energy sector requires adequate evaluation and support from the State.

Legend

AIC - agro-industrial complex;

RES – renewable energy sources;

EU – European Union;

EBRD – European Bank on Reconstruction and Development;

VAT – value added tax;

CMU – Cabinet of Ministers of Ukraine;

GT – «green» tariff;

CHP – combined heat and power plant;

SAEE – State Agency on Energy Efficiency and Energy Saving of Ukraine;

NERC – National Energy Regulatory Commission of Ukraine;

NSDC - National Security and Defense Council of Ukraine;

UAH – Ukrainian hryvnia currency code;

NG –natural gas;

MSW –municipal solid waste;

LFG – landfill gas.

Previous UABIO publications

1. First position paper “Position of bioenergy in the draft updated Energy Strategy of Ukraine till 2030” http://uabio.org/img/files/docs/position-paper-uabio-1-en.pdf
2. Second position paper "Analysis of the Law of Ukraine «On amendments to the Law of Ukraine «On Electricity» N5485-VI of 20.11.2012" http://uabio.org/img/files/docs/position-paper-uabio-2-en.pdf
3. Third position paper "Barriers to the development of bioenergy in Ukraine" http://uabio.org/img/files/docs/position-paper-uabio-3-eng.pdf

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Public Union "Bioenergy Association of Ukraine" (UABIO) was established to create a common platform for cooperation on bio-energy market of Ukraine to ensure the most favorable business environment, fast and sustainable development of bioenergy. Total constituent assembly UABIO was held September 25, 2012 in Kiev. The Association was officially registered on April 8, 2013. Among UABIO members there are more than 10 leading companies and more than 20 acknowledged experts in the field of bioenergy.
http://uabio.org