Bioenergy Association of Ukraine

PROSPECTS FOR THE ELECTRICITY GENERATION FROM BIOMASS IN UKRAINE

UABio Position Paper N5

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31 May 2013

Discussion within UABio: from 18.05.2013 to 31.05.2013
Approval by the Board of UABio and publication at www.uabio.org: 31.05.2013
The publication is available at www.uabio.org/activity/uabio-analytics
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Contents

Introduction

The Position Paper N5 of Bioenergy Association of Ukraine (UABio) is a regular document of the planned series of publications on key issues of bioenergy development in Ukraine.

In the Paper, the current state and prospects of the sector of electricity generation from biomass in the world, the EU countries and Ukraine are considered. The potential of the sector of electricity generation from biomass in Ukraine is analyzed, the main barriers are considered and a concept of bioenergy equipment application for electricity generation for the period till 2030 is offered.

General characteristic of the electricity generation from biomass in the world and its development prospects

An actual level of the electricity generation from RES and biomass in the EU countries is given in **Table 1**. At the beginning of 2011, the share of RES in the total electricity generation was 21% (3.7% from biomass). Leaders in the electricity generation from biomass are the following countries: Finland – 13.6%, Denmark – 11.9% Austria – 6.4%, and the Netherlands – 5.9%. At the same time, Ukraine generated only 0.175% of its electricity from renewable energy sources, including 0.005% from biomass.

Table 1 – Electricity generation in the EU countries including from RES and biomass, TWh, %[1]

Country	2000	2005	2010	including from RES:		including from BM within RES		% from RES to total
EU-27	***3025.2***	***3310.6***	***3345.6***	***699.3***	***20.9%***	***123.3***	***17.6%***	***3.7%***
Denmark	36.05	36.25	38.79	12.47	**32.1%**	4.63	**37.1%**	***11.9%***
Germany	576.54	620.57	627.92	110.53	**17.6%**	33.67	**30.5%**	***5.4%***
France	540.73	576.20	569.00	82.59	**14.5%**	4.7	**5.7%**	***0.8%***
Netherlands	89.63	100.22	118.14	11.2	**9.5%**	7.04	**62.9%**	***5.9%***
Austria	61.26	66.41	71.13	48.3	**67.9%**	4.55	**9.4%**	***6.4%***
Poland	145.18	156.94	157.66	11.46	**7.3%**	6.3	**55.0%**	***4.0%***
Finland	69.97	70.57	80.67	24.18	**30.0%**	10.96	**45.3%**	***13.6%***
Sweden	145.27	158.44	148.61	6.32	**4.3%**	0.66	**10.4%**	***0.4%***
Ukraine[2]	**173**	**186.1**	**188.8**	**0.3328**	**0.175%**	**0.0104**	**3.12%**	***0.005%***

The main fuel in the process of the electricity generation from biomass is solid biomass[3] – 60%, biogas – 25% and MSW – 15% (**Fig. 1**). The largest volume of electricity generation from solid biomass was reached in Germany, Finland and Sweden – about 10 TWh. Germany is the leader of the biogas production and use – 16 TWh, other countries generate 0.3-1 TWh on average. MSW is an important source of energy. In the EU about 17.2 TWh of electricity is generated from MSW. The leaders in the MSW utilization use are Germany, France, the Netherlands and Sweden.

[1] EU Energy in figures, 2012

[2] State Energy on Energy Efficiency and Energy Saving of Ukraine. Information on renewable energy objects. Statistical yearbook, 2011.

[3] EUROBSERV`ER - The state of renewable energies in Europe, 2011.

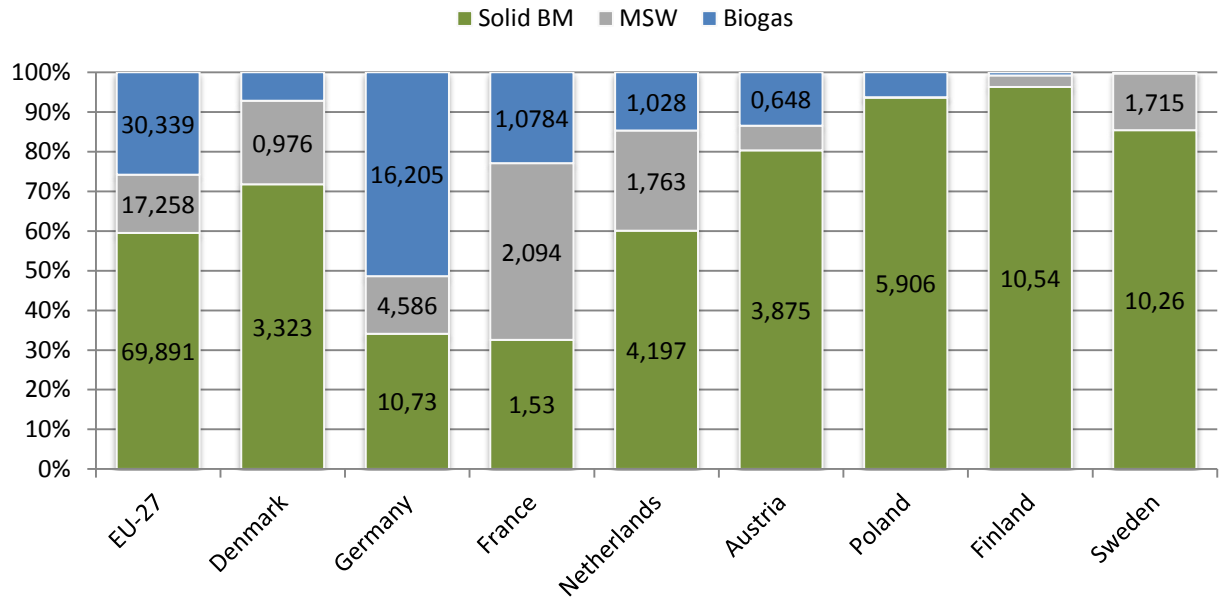

Fig. 1 – The biomass sources distribution in the electricity generation in the EU countries, TWh, %

In the EU-27, ratio of the electricity generation among CHPPs and TPPs is about 50/50%. In Denmark and Sweden, electricity from biomass is only generated by CHPPs and cogeneration units. In Germany, TPPs produce 82% of electricity that is connected with a high proportion of co-firing of biomass with coal in coal-fired TPPs and the significant contribution of biogas, when the thermal energy consumption is usually absent in the electricity production. The major share of electricity in the EU-27 is generated by TPPs from biogas– 81%, solid biomass – only 36%, MSW – about 54%. The distribution of the installed electric capacity of the electricity generation and the electricity generation from biomass is given in **Table 2**. In the EU, the largest installed capacity of a wood power plant is about 15 GW, a biogas power plant – about 6 GW, a MSW power plant – about 6 GW, an industrial waste power plant – 0.6 GW.

Table 2 – Installed electric capacity in the EU countries and Ukraine, MW[1]

Country	2000	2005	2010:	wood	biogas	municipal waste	industrial waste
EU-27	***672650***	***768632***	***904125***	***15381***	***6113***	***6201***	***604***
Denmark	12671	13987	14956	868	80	300	-
Germany	120325	128535	163766	2014	2725	1650	119
France	114681	116784	125918	375	187	858	-
Netherlands	21586	23138	28171	686	196	586	-
Austria	18597	20004	24826	2394	586	459	267
Poland	30571	32315	33497	53	81	-	3
Finland	17761	18888	18579	1910	-	-	-
Sweden	35306	36369	40375	3142	22	654	100
Ukraine	**-**	**-**	**52957**	**2.5**	**3.8**	**-**	**1.7**

Taking into account the experience of the previous years and the RES development potential and prospects, the European Commission predicts further growth of RES share in the energy

generation both by 2030 and by 2050[4]. One of the scenarios of the most intensive RES development considers the possibility of RES share increase up to 75% in the final energy consumption by 2050.

In the new EU Energy Plan in 2007, the goal was set to reach 20% of RES in the total energy consumption in 2020. In the Road Map on RES[5], the assessment of pace of development of different RES sectors, including bioenergy, was done and it was analyzed ways through which the achievement would be done. The European Commission asked the EU countries to set their own national targets for the RES development in all sectors (electricity, heat energy and transport) and to represent the goals and ways of their achievement in the national Action Plans on RES. Today, every EU country has the Biomass Action Plan as a part of the National Action Plan on RES.

The majority of the EU-27 countries have an intention to increase the share of RES in the electricity generation up to the level of 20-30% (mainly from biomass). For example, it is planned to increase the share of RES in the total energy consumption up to 48% in Sweden by 2020, up to 40% in Latvia, up to 38% in Finland, up to 30% in Denmark, up to 18% in Germany, and up to 10% in Malta (the lowest rate). In the EU-27, the general forecast on consumption of RES and BM till 2030 is given in **Table 3**. It is planned to increase the electricity generation from RES in the EU from 21% to 66%, and to double the share of BM up to the level of 8% in 2030.

Table 3 – RES and biomass consumption forecast in the EU-27 till 2030.

Balance item	**Unit measure**	**2010 (Actual)**	**Forecast**			
			2015	**2020**	**2025**	**2030**
	All energy					
RES share in the energy consumption	% to total	10 %	15 %	20 %	32 %	**43 %**
BM share in the energy consumption	% to total	6.7 %	10 %	14 %	16 %	**19 %**
	Electricity					
RES share in the electricity generation	% to total	21 %	27 %	34 %	50 %	**66 %**
BM share in the electricity generation	% to total	3.7 %	5.5 %	7.3 %	7.6 %	**8 %**

While the European average share of the electricity generation from RES will be 34% in 2020, it will be 52% in Denmark, 39% in Germany, and 71% in Austria. At the same time, the share of biomass in the structure of the electricity generation from RES is in the rage from 5% to 63%, while an average share in the EU is about 17%[6].

National action plans on the RES development contain the relevant forecasts of the installed capacity and electricity generation increase in 2020 (**Table 4**): Denmark – 2780 MW, Germany – 8825 MW, the Netherlands – 2892 MW, Austria – 1281 MW and Sweden – 2914 MW. Denmark plans to increase the installed capacity on solid biomass by 225% and on biogas by 843%. Similar plans are in Germany – 97% and 448% correspondingly.

The detailed analysis of the stimulating mechanisms of the bioenergy development in the EU, in particular the electricity generation, is presented in the UABio's Position Paper N3[7]. Among the basic mechanisms the following should be noted: market prices and additional taxes on fossil fuels, stimulating green tariffs and green certificates for the electricity generation from RES, governments support, subsidies for equipment, high state goals and the functioning state policy on

[4] Energy Roadmap 2050, European Commission.
[5] Renewable Energy Road Map. Renewable energies in the 21st century: building a more sustainable future. COM (2006) 848 final, Brussels, 10.01.2007.
[6] National action plans on RES development (NREP) in the EU countries
[7] Position Paper N3 "Barriers to the development of bioenergy in Ukraine"

the RES development.

Table 4 – Planned achievement of biogeneration capacity in the EU-27, MW[5,6]

Total, including:	Forecast				
	2005	**2010**	**2015**	**2020**	Increment, % as compared with 2005
Denmark, including	777	1017	1837	2779	258%
- solid BM	740	991	1717	2404	225%
- biogas	37	26	95	349	843%
Germany, including	3174	6312	7721	8825	178%
- solid BM	2427	3707	4358	4792	97%
- biogas	693	2368	3126	3796	448%
Netherlands, including	1128	1430	2443	2892	156%
- solid BM	966	1214	2062	2253	133%
- biogas	162	216	381	639	294%
Austria, including	976	1211	1228	1281	31%
- solid BM	892	1099	1114	1164	30%
- biogas	72	97	100	102	42%
Finland, including	2140	1790	2200	2920	36%
Sweden, including	2568	2683	2799	2914	13%
- solid BM	2526	2641	2757	2872	14%
- biogas	42	42	42	42	0%

Development of the electricity generation from biomass in Ukraine

Comparing the Ukraine's GDP energy intensity with other countries, it should be noted that it is 2.6 times higher than in developed countries[8]. This situation greatly limits the competitiveness of domestic products at the world markets, holding back the development of the national economy, creates Ukraine's dependence on imported energy sources, which threaten the economic, energy and general national security. The main factors of the high GDP energy intensity is the structure of the industrial production, the high power consumption of fuel and energy and metallurgical sectors, the low production energy efficiency, the monopolization of the energy sector and the inefficiency of the government policy.

Ukraine is an energy-dependent country, and it meets the demands in energy resources at only 60.9%[9]. Proposed directions for the development of different energy sectors in Ukraine in the draft Updated Energy Strategy of Ukraine till 2030 in general do not coincide the trends of the renewable energy and bio-energy development in the EU. The detailed analysis of bioenergy place in the Updated Energy Strategy was carried out in the UABio's Position Paper N1[10]. Objectives for the electricity generation from biomass are considerably understated. It is planned that in 2030 the electricity production from biomass will be only 2.4% of the total electricity generation from RES or 0.1% of the total electricity generation in Ukraine. In comparison with the EU, the electricity generation from RES in 2030 will be at the level of 66%, including 8% from biomass **(Table 3)**.

[8] I. Mazur. Ukraine's GDP energy intensity: preconditions for lowering. Ternopil Economic University Bulletin N1, 2012 (in Ukrainian)
[9] Ukraine 2012. Fundamentals and recommendations. General energy policy // International Energy Agency. – 2012. – 38 p. (in Ukrainian)
[10] UABIO's Position Paper №1 «Position of bioenergy in the draft updated energy strategy of Ukraine till 2030».

Ukraine has good preconditions for the future development of this field of activity, especially in the bioenergy sector because Ukraine has a large potential of biomass available for energy generation. The main components of the potential are agricultural waste, wood waste, and in prospect – energy crops, growing of which has been actively developing lately[11,12].

At the beginning of 2013, the total installed capacity of power generation facilities connected to the united power system in Ukraine was 53.777 GWh, including about 670 MW from RES: wind power plants – 262.8 MW, solar power plants – 317 MW, small hydropower plants – 78.1 MW, biomass TPPs/CHPPs – 9.9 MW[13]. By May 2013, the installed electrical capacity of renewable energy facilities had increased up to 741.9 MW, including biomass power plants – 6.2 MW and biogas power plants – 3.78 MW.

In May 2013, the total number of objects of the electricity production from RES connected to the electric grid and obtained the "green" tariff was 145, and of these only 3 objects use biomass as a fuel, and only one is a biogas cogeneration plant[14] **(Table 5)**.

In 2012, LLC "Smilaenergopromtrans" replaced a 2.5 MW steam turbine by a new one of 6 MW. The first stage of the 6 MW TPP in Ivankov district, Kyiv region, is in the process of construction. Several TPP/CHPP projects with total capacity of 50 MW are under the preparation stage. Landfill gas collection systems and the electricity generation are implemented at more than 8 sites, including the construction of about 7 BPs. The agricultural holding company "Ukrlandfarming", one of the largest agricultural producers in Ukraine, plans to implement more than 30 BPs with a total capacity of 200 MW[15].

The main motivating factor for the development of the sector is availability of the "green" tariff for electricity generated from RES. The basic provisions of the "green" tariff are stated in the Law of Ukraine "On Electricity" with amendments[16]. The "green" tariff is calculated based on a retail tariff for consumers with the second class of voltage for January 2009 (58.46 UA kopecks/kWh excluding VAT) multiplied by the "green" tariff coefficient. For electricity generated from biomass and biogas the coefficient is 2.3. The minimum green tariff for electricity generated from biomass is fixed – 134.46 UA kopecks/kWh excluding VAT (12.39 €cents/kWh). The detailed analysis of the problems of the "green" tariff in Ukraine was conducted in the UABio's Position Paper N2[17].

The approved "green" tariff for electricity from biomass has been remaining the same (1.3446 UAH/kWh excluding VAT) since 2012. However, the electricity tariffs for consumers increase steadily: for the 1st voltage class – 79.52 UA kopecks/kWh excluding VAT and for the 2nd voltage class – 101.22 UA kopecks/kWh excluding VAT (May 2013)[13].

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[11] Geletukha G.G., Zheliezna T.A., Zhovmir M.M., Matveev Yu.B., Drozdova O.I. Assessment of energy potential of biomass in Ukraine. Part 2. Energy crops, liquid biofuels, biogas (in Ukrainian) // Industrial Heat Engineering. – 2011, v. 33, N 1, p. 57-64.

[12] Geletukha G.G., Zheliezna T.A., Zhovmir M.M., Matveev Yu.B., Drozdova O.I. Assessment of energy potential of biomass in Ukraine. Part 1. Agricultural residues and wood biomass (in Ukrainian) // Industrial Heat Engineering. – 2010, v. 32, N 6, p.58-65.

[13] Web site of NPC "Ukrenergo"

[14] Web site of National Commission for the State Regulation in Energy

[15] V. M. Dmytrenko. "Biogas plants in Ukrainian reality. An example of an agricultural holding Avangard", 2012.

[16] The Law of Ukraine "On Electricity" № 575/97-BP of 16.10.1997

[17] Position Paper N2 "Analysis of the Law of Ukraine "On amending the Law of Ukraine "On Electricity" №5485-VI of 20.11.2012"

Table 5 – Power generation plants (from biomass and biogas)

№	Name	Installed capacity, MW	Electricity production in 2012, GWh	Green tariff
1	LLC "Kirovogradoil", CHPP, sunflower husk	1.7	10.988	+ 1 January 2010
2	LLC "Smilaenergopromtrans", CHPP, wood chips	2.5	6.674	+ 1 June 2010
3	Private joint-stock company "Kargil plant", CHPP, sunflower husk	2.0	0.0	+ 27 December 2012
4	LLC "Ukrainian milk company", gas turbine CHP plant, biogas from manure + corn silage	0.625	0.278	–
5	LLC "Spetsgazremtehnologia"	1.0	0.0	–
6	LLC "West Ukrainian gas technologies"	1.0	0.0	–
7	LLC "LNK", Boryspil MSW landfill, gas turbine CHP plant, biogas from MSW	1.0	0.0	+ 1 May 2013
8	LLC "LNK", Kyiv MSW landfill, gas turbine CHP plant, biogas from MSW	5×0.177	0.0	–
9	LLC "Terezino", biogas from manure	0.25	0.0	–
10	LLC "Tis Eko", Mariupol MSW landfill, gas turbine CHP plant, biogas from MSW	0.17	0.0	–

At present, the stimulation and development mechanisms of the RES sector in Ukraine in general and bioenergy in particular can be divided into the following categories: customs remissions[18] – remission from customs taxes, tax relieves[19]; stimulation mechanisms, such as the "green" tariff for electricity generated from RES; the development strategy, the government programs etc. It should be noted that at this time, in spite of existing stimulation mechanisms of the bioenergy development, in reality it is not possible to obtain benefits from the offered privileges in majority of cases. This is due to the lack of the procedures transparency, a selective approach to projects and their owners, which creates additional barriers to widespread implementation of bioenergy equipment in Ukraine.

Existing barriers of the development of the electricity generation from biomass in Ukraine

The detailed analysis of barriers for bioenergy development in Ukraine was conducted in the UABio's Position Paper N3[7]. In the present Position Paper we will consider only those barriers that relate to the sector of the electricity generation from solid biomass and biogas.

[18] Custom Code of Ukraine. The Law of Ukraine of 13.03.2012 № 4495-VI
[19] Tax Code of Ukraine. The Law of Ukraine of 02.12.2010 № 2755-VI

The stimulation mechanism of the electricity generation from biomass in Ukraine – the "green" tariff – does not work in practice, largely because of the new regulations introduced by the Law of Ukraine On amendments to the Law of Ukraine «On Electricity» concerning stimulation of the electricity generation from alternative energy sources (No.5485-VI of 20.11.2012). The detailed analysis of the law was conducted in the UABio's Position Paper N2[17], where the main barriers were highlighted:

1. *Incorrect definition of the term "biomass".*
2. *Unreasonably low "green" tariff rate for power generated from biogas.*
3. *Unjustified requirement concerning the local content share of equipment, materials, and services in the total project cost.*
4. *Terminological mistakes in the description of main pieces of equipment for power generation objects which use energy of biomass and biogas.*
5. *Discriminatory approach towards biogas plants which were put into operation before 01.04.2013.*
6. *Absence of the "green" tariff for electricity generated from municipal solid waste*
7. *Absence of the "green" tariff for electricity generated via co-firing of biomass and fossil fuels.*
8. *Absence of the government subsidies and leasing mechanisms for buyers of bioenergy equipment.*
9. *Absence of the effective state program for the bio-energy development.*
10. *Opportunities of the bioenergy sector are almost ignored in the drafting of the updated Energy Strategy of Ukraine till 2030.*
11. *The complexity of the tax and customs privileges application.*

UABio's suggestions for overcoming the above mentioned barriers relate to changes in the relevant laws of Ukraine, in particular:

1. *The definition of "biomass" shall comply with international and European practice on this issue and include not only wastes of organic origin, but also the products, as well as residues of forestry and agriculture.*
2. *To set the following "green" tariffs for electricity generated from biogas: 3.0 – for power generated from biogas, which is produced from biomass of agricultural origin; 2.7 – for other types of biogas.*
3. *To abolish local content requirements for the projects applying for the green tariff for electricity generated from biomass and biogas.*
4. *To abolish the discriminatory approach towards all plants and electricity generation facility which were put into operation before 01.04.2013.*
5. *To set the "green" tariff for electricity generated from municipal solid waste at least at the rate of 3.0.*
6. *To set the "green" tariff for electricity generated from biomass co-firing with fossil fuels at least at the rate of 1.9.*
7. *To organize at the state level the process of bioenergy equipment purchase subsidy of 20*

... 30% of its price.

8. *To prepare and to approve the action plan for the bioenergy development based on the methodology of the European Commission at the government level.*
9. *To set appropriate goals for the bioenergy development, particularly in the updated Energy Strategy of Ukraine till 2030 (**Table 6**).*
10. *To develop and to adopt standards for different types of solid biofuels, as well as programs to promote investments in the infrastructure of harvesting, storing and supplying of biofuels.*
11. *To simplify the procedure of obtaining the tax and customs exemptions, to increase transparency and to reduce the time for decision-making on this issue.*

Table 6 – The targets for the biomass contribution in the energy balance of Ukraine.

Indicator	2011	2015	2020	2025	2030
BM share in the general energy consumption	1.24%	1.5%	3%	5%	7%
BM share in the gross final energy consumption	1.78 %	2.2 %	4.3 %	7.2 %	10 %
BM share in the electric power distribution	**0.01 %**	**0.2 %**	**1 %**	**2.2 %**	**4 %**

The concept of the development of the sector of the electricity generation from biomass in Ukraine

At present, several documents which aimed to develop the electricity production from RES and biomass in Ukraine are developed. However, their status, goals and funding sources do not secure unified national strategy for the renewable energy development and do not assure the set goals achievement.

On this basis, it may be concluded that there is an urgent need in developing of the concept "Implementation of the biomass use at TPPs, CHPPs and cogeneration plants in Ukraine" (hereinafter – the Concept). This Concept could be a part of an overall government strategy, which is to be approved at the state level, and the tasks of its implementation and the achievement of the objectives will be taken as the basis for the government bodies and the state departments. The purpose of the Concept should be ensuring of the collaboration of Ukrainian and European integrated power systems.

In this section, the basic approaches and supporting information of the need of the Concept development and implementation are presented. The basis of the analysis was the European experience in developing of concepts and state programs of the bioenergy development and practical experience in achieving of set goals, as well as the main approaches and forecast of the energy resources production and consumption.

The main objective of the Concept is the introduction of the biomass use for TPPs, CHPPs and cogeneration plants in Ukraine. To implement the Concept, the necessary laws, regulations and provisions should be developed and implemented by relevant government bodies and state departments.

The main objectives of the Concept, which should ensure the achievement of the goals, are:

– To set and ensure the achievement of the RES and biomass share in the electricity generation, which meets the common European trends in the development of renewable energy,

taking into account technical, environmental, financial and social opportunities of Ukraine;

– To fix at the state level national, regional, sectoral targets of the electricity generation from biomass and assign the responsible public authorities for the implementation and achievement of the objectives;

– To improve the legal framework, to create equal competitive conditions and support for the market participants for the wide bioenergy development in Ukraine;

– Approaching of Ukraine to the European Union requirements regarding the implementation of the Energy Community and the fulfillment of its obligations to reduce the negative impact of the heat and electricity generation on the environment.

The main expected results of the proposed Concept till 2030: it is assumed that during this period, the necessary conditions for the successful achievement of the objectives will be formed, in particular:

–share of biomass in the primary energy consumption will be not less than **7% in 2030**;

–share of biomass in the gross final energy consumption will be at least **10% in 2030**;

–share of biomass in the electricity distribution will be not less than **4% in 2030**.

The basis for the development of the Concept is the basic scenario of the updated Energy Strategy, which sets the estimated demand for fuel and energy, forecasts of the primary energy consumption till 2030 (**Table 7**).

Table 7 – Forecast of the energy resources consumption and the total electricity generation and consumption till 2030.

Balance item	Unit	2010	Forecast			
			2015	2020	2025	2030
Primary energy consumption	Mtce	190.7	200.9	212.8	223.1	238.1
Electricity generation	bln kWh	189.9	215	236	259	282
Electricity consumption	bln kWh	152.9	186.5	208.5	231.4	253.5

In accordance with the proposed Concept (**Table 8, Fig. 2, 3**), it is planned to increase the share of biomass in the energy consumption from 0.7% to 10% in 2030, which corresponds to the level of BM consumption in the EU-27 in 2010.

Table 8 – Concept of RES and biomass consumption till 2030 in Ukraine.

Balance item	Unit	2011	Forecast			
			2015	2020	2025	2030
BM share in the total energy consumption	% of total	1.24%	1.5%	3%	5%	7%
BM share in the gross final energy consumption	% of total	1.78 %	2.2 %	4.3 %	7.2 %	10 %
BM share in the electricity generation	% of total	**0.01 %**	**0.2 %**	**1 %**	**2.2 %**	**4.0 %**

It is planned to increase the share of electricity generated from RES from 0.32% to 20%, which corresponds to the EU-27 goals in 2015. At the same time, it is planned to generate about 20% of electricity from RES, and share of BM will be not less than 4.0% in 2030.

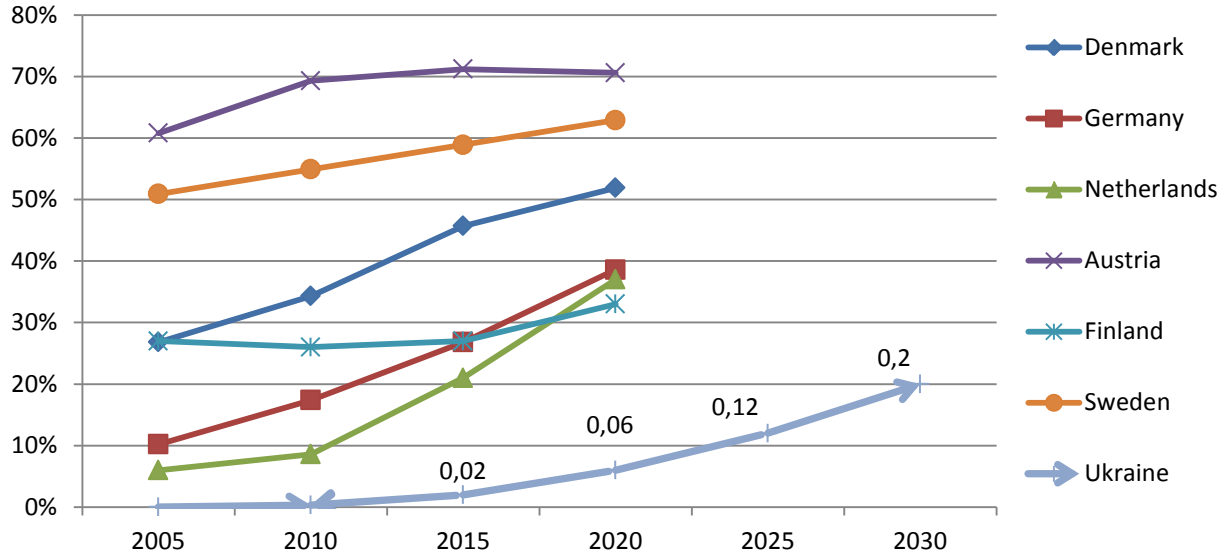

Fig. 2 – The share of RES in the electricity generation in the EU and Ukraine till 2030, %.

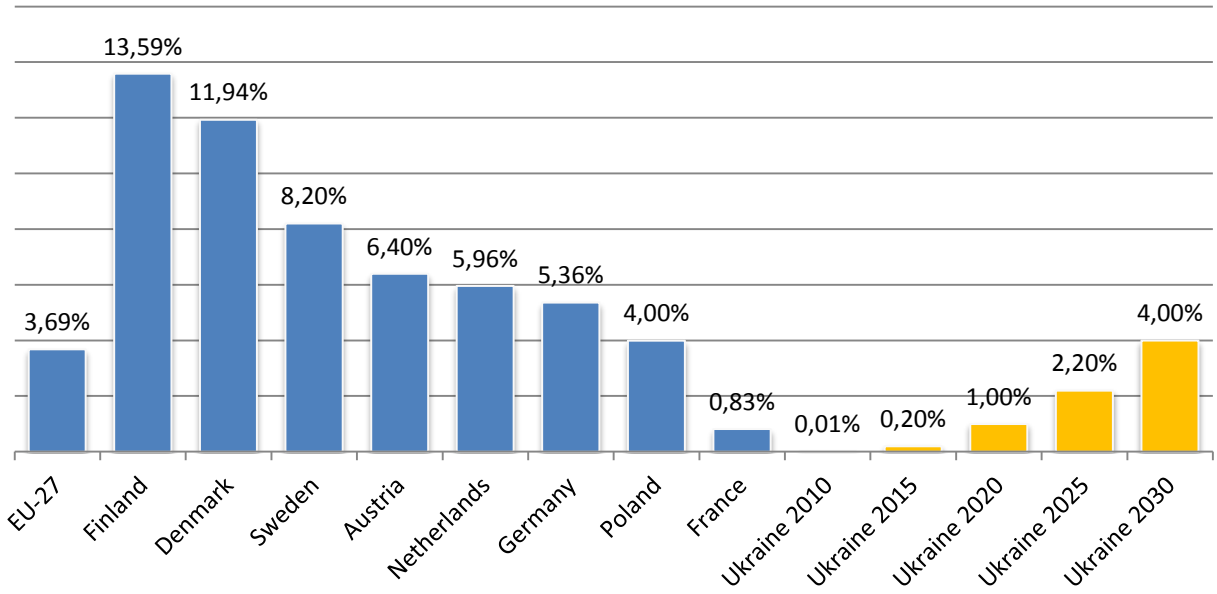

Fig. 3 – The share of biomass in the electricity generation in the EU in 2010 and in Ukraine till 2030, % of total.

To achieve these goals, all the available technologies of fuel energy conversion into useful heat and electricity should be allowed at the legislative level. Co-firing of biomass with fossil fuels, the technologies of direct combustion, gasification, anaerobic digestion, pyrolysis, gasification etherification, hydrolysis, fermentation, including direct energy conversion technologies and others can be successfully used for different fuels and wastes [20,21,22,23].

As the drives of power generating equipment, steam-power and gas-power units, engines of internal and external combustion, including steam and gas turbines, screw and piston steam engines,

[20] Booklet "Bioenergy for electricity and heat – experiences from biomass-fired CHP plant in Denmark".
[21] Booklet "Wood for energy production. Technology – Environment – Economy".
[22] Booklet "Straw for energy production. Technology – Environment – Economy".
[23] Booklet "Production and use of biogas in Ukraine"(in Ukrainian)

piston internal combustion engines, Stirling engines, hot air gas turbines, etc. can be used.

The organization of the electricity generation from biomass is planned to implement in both existing power generating facilities and new ones, which are planned to be put into operation. For the purpose of the widespread use of biomass for electricity generation, it is planned to develop actively the co-firing technologies of biomass at existing coal-fired power plants and technologies of anaerobic digestion of animal waste with co-substrate.

The advantage of the co-firing technology is the use of existing generating capacity, low capital cost of the re-equipment and conversion of the fuel energy into electricity with the high efficiency (30-36%). In particular, pulverized coal-fired technologies are the most common and may be successfully implemented at the coal-fired TPPs in Ukraine. Under suitable market conditions co-firing technologies will be quickly implemented in Ukraine. They could provide up to 5% of electricity from biomass at coal-fired TPPs. In the long-term prospect, it is planned to reconstruct coal-fired plants with their re-equipment with modern and more efficient environmentally friendly technologies of combustion in a fluidized bed and a circulating fluidized bed, which will increase the share of biomass for co-firing technologies for more than 5%.

It is already decided that some of the existing CHPPs in Ukraine, including modern ones, which are equipped with flame combustion steam boilers and usually burn gas and fuel oil, and steam turbines with heat and industrial extractions are going to be re-equipped on coal burning. There are over 35 existing TPPs and CHPPs in Ukraine. Taking into account that Ukraine had the total installed capacity of TTPs and CHPPs of 33.890 GW[13] in 2012, a significant consumer demand for electricity by 2030 could be achieved by utilizing biomass and by increasing load demand at existing units of TPP and CHPP.

The potential of implementing technologies for collecting biogas from landfills and generating electricity by CUs is based on estimating the existing amount of MSW at landfills and town dumps in Ukraine, as well as its annual increase. From the economic and technical points of view, CU construction is reasonable for landfills located near cities with the population of over 100 thousand people. For a city with population of 100-200 thousand people the total amount of accumulated MSW is about 0.7 million tons, for a city with population of 200-500 thousand people – 1.6 million tons and for a cities with population of over 500 thousand people – 3.5 million tons.

In Ukraine, the generation of biogas from MSW with 50% methane content is 4.0 m^3/t of MSW per year on average or 20.0 million m^3 for all cities with population over 100 thousand people. Taking into account collection efficiency for the biogas from landfills (~50%) and the electrical efficiency of CUs, their potential implementation capacity is up to 400 kW on the average for 13 cities with the population of 100-200 thousand people, 900 kW for 23 cities with the population of 200-500 thousand people, 1950 kW for 9 cities with the population of more than 500 thousand people. The total capacity of these CUs using landfill gas is about 43 MW. It enables to generate about 350 mln. kWh of electricity annually. Thus, the share of electricity generated from landfill gas can be about 0.18% of the total electricity generation.

The potential of the energy use of biogas which is produced by anaerobic digestion of available waste from livestock enterprises (pig farms, cattle farms, poultry farms), beet pulp with sugar mills, beet leaves, grains of malt from breweries and grain stillage from distilleries is approximately 1.360 mln. m^3 of biomethane (1.58 mln. tce). The use of the all available potential of biogas will allow generating about 10 mln. Gcal of heat energy in boiler houses or 4.9 mln. MWh of electricity and 5.7 mln. Gcal of heat energy by using of CUs. Thus, the share of electricity generated from agricultural waste biogas may be about 2.6% of the total electricity generation in 2010, for which the total installed capacity of CUs should be more than 615 MW. The prospects for

development of the energy generation from biomass were considered in detail by the International Energy Agency[24].

The proposed Concept suggests that in the near-term prospect (till 2015) the most easily available technical solutions will be implemented and required generating capacity on solid biomass (75%) and biogas (25%) will be put into operation, which will provide about 0.2% of the total electricity generation (**Table 9**). Detailed analysis of the biogas energy use was carried out in UABio's Position Paper N4[25]. The main share of electricity from biomass (47%) will be generated from solid BM at CHPPs, 28% at TPPs and 25% from biogas at cogeneration plants. By 2030, it is planned to generate electricity from biomass at coal-fired power units (16%), biomass TPPs and CHPPs will provide 47%, from MSW – 12%, from biogases – 25%. Not less than 60% of biogeneration will be implemented in the combined cycles.

The Updated Energy Strategy suggests implementation of energy efficiency actions aimed at improving the efficiency of the electricity generation and the reduction in equivalent fuel consumption. According to the NJSC "Energy Company of Ukraine"[26], which manages the state-owned coal-fired TPPs, the equivalent fuel consumption for the electricity production in 2011 was 362-419 kg c.e./kWh. It corresponds to the electrical efficiency of the plants at level of 34-30%. It is planned that by 2030, an average per capita consumption of equivalent fuel will be decrease by 12.5% to reach the level of fuel consumption of 0,347 kg c.e./kWh[27]. The equivalent fuel consumption at the existing CHPPs of general use and customer's plants is taken on the basis of statistical data[28] and the prospects for improving of the energy efficiency by 2030.

Table 9 – Shares and electricity generation from biomass till 2030.

Balance item	Unit	2010	Forecast			
			2015	2020	2025	2030
Electricity production from RES, including	**bln kWh**	**0.6077**	**4.3**	**14.16**	**31.08**	**56.4**
Biogeneration, total, including:	***bln kWh***	***0.0095***	***0.43***	***2.36***	***5.7***	***11.3***
Reconstructed coal TPP	bln kWh	-	-	0.4248	0.9687	1.8048
BM TPP	bln kWh	-	0.1204	0.2360	0.4558	0.6768
BM CHPP	bln kWh	0.0090	0.2021	0.9440	2.3932	4.6812
MSW TPP/CHPP	bln kWh	-	-	0.1888	0.5698	1.3536
MSW BG CU	bln kWh	0.0005	0.0344	0.1180	0.1709	0.226
BG CU	bln kWh	0.0000	0.0731	0.4484	1.1396	2.538
Reconstructed coal TPP	% . biogeneration	-	-	18 %	17 %	16 %
BM TPP	% . biogeneration	-	28 %	10 %	8 %	6 %
BM CHPP	% . biogeneration	95 %	47 %	40 %	42 %	41.5 %
MSW TPP/CHPP	% . biogeneration	-	-	8 %	10 %	12 %
MSW BG CU	% . biogeneration	5 %	8 %	5 %	3 %	2 %
BG CU	% . biogeneration	-	17 %	19 %	20 %	22.5 %

The equivalent fuel consumption for new biomass TPPs, biomass CHPPs and biogas CUs are given in **Table 10**. It is planned to introduce biomass condensing TPPs with an average parameters of 24-39 bar and 380-440 °C in the near future. In long-term prospects, it is planned to introduce TPPs with higher operating parameters (60-90-150 bar and the temperature of overheated

[24] IEA. Technology Roadmap. Bioenergy for Heat and Power
[25] Position Paper N4 "Prospects of biogas production and use in Ukraine".
[26] Website NJSC "Energy company of Ukraine".
[27] Energy strategy of Ukraine until 2030 (in Ukrainian)
[28] Statistical Yearbook 2010. Specific consumption of fuel and energy in Ukraine. 2011 (in Ukrainian).

steam up to 525 °C), which will increase the efficiency of the electricity generation and will reduce the fuel equivalent consumption to 0,483 kg c.e./kWh. Biogeneration at CHPPs will be implemented both with the use of back pressure steam turbines and with the use of condensing turbines with adjustable extraction of heat energy with a gradual increase of the steam operating parameters. It will reduce the equivalent fuel specific consumption from 0.585 kg c.e./kWh to 0.515 kg c.e./kWh.

Table 10 – Fuel consumption in the electricity generation from biomass, kg c.e./kWh*

Balance item	Unit	2010	Forecast			
			2015	2020	2025	2030
Electricity generation at CHPP of general use	kg c.e./kWh	**0.3208**	0.3156	0.3104	0.3052	0.3
Electricity generation at CHPP by customer' plants	kg c.e./kWh	**0.3864**	0.3748	0.3632	0.3516	0.34
Electricity generation at TPP of general use	kg c.e./kWh	**0.397**	**0.395**	**0.389**	**0.366**	**0.347**
Electricity generation from biomass at TPP	kg c.e./kWh	**0.586**	0.539	0.525	0.517	0.483
Electricity generation from biomass at CHPP	kg c.e./kWh	**0.585**	**0.57**	**0.535**	**0.525**	**0.515**
Electricity generation from biogas at CU	kg c.e./kWh	**0.323**	0.316	0.309	0.302	0.295

* Authors' calculations

The efficiency of the electricity generation at CUs is about 38%. More efficient CUs will be introduced in prospect, which will increase the electrical efficiency of up to 42% and reduce fuel consumption by 7% to 0.295 kg c.e./kWh until 2030.

In order to determine the necessary installed capacity for the generation of the required volume of electricity, it should be taken into account that the process of a biomass TPP or a biomass CHPP construction takes about 1-2.5 years depending on the capacity. Therefore, ICUF (installed capacity utilization factor) for the relevant planning period will be significantly lower than for the averaged operating period. The average ICUF for the above mentioned countries increases by 29%, including solid biomass ICUF – 8%, and reaches 41-61%, biogas ICUF increases by 40% and reaches the level of 65-80%.

The minimum required installed capacity of power generation equipment is given in **Table 11**. Until 2030, it is necessary to put into operation equipment of about 2133 MW capacity, of which about 390 MW is necessary for co-firing of biomass with coal in existing coal-fired power units. The share of biomass in co-firing in power units with the capacity of more than 300 MW will not exceed 5%. The total installed capacity for a biomass TPP should be no less than 110 MW, for CHPP – not less than 890 MW, for MSW TPP and CHPP – about 260 MW, for biogas from landfills CU – about 40 MW, and for biogas CU – approximately 446 MW. Thus, the total installed capacity for solid biomass and MSW should be about 1.650 MW and 486 MW for biogas.

Estimation of the required volume of investments for implementation of proposed measures was done on the basis of averaged specific capital costs of "turnkey" projects. Accepted in **Table 12** specific capital costs are based on analysis of the worldwide and European experience in bioenergy projects implementation as well as the IEA data[29,30]. By 2030, the total required volume of investments will be approximately 69.5 bln UAH (on the average 3.8 bln UAH annually). Private investments and bank capital must be attracted for the projects implementation.

[29] According to data of International Energy Agency

[30] IRENA. Renewable energy technologies: cost analysis series. Biomass for Power Generation.

Table 11 – Installed electric capacity of biogeneration objects.

Balance item	Unit	2010	Forecast			
			2015	2020	2025	2030
Minimum required installed capacity	**MW**	**4**	**112**	**533**	**1181**	**2133**
Biomass installed capacity increment, total, including the increment	**MW**	**-**	**108**	**421**	**648**	**951**
Reconstructed coal TPP – Cf	MW	0.0	0.0	91	230	389
Share of the electricity production at coal-fired power units (under 300 MW)	%	0 %	0 %	1 %	2.5 %	4.2 %
BM TPP	MW	0.0	31	54	87	110
BM CHPP	MW	4.1	51	215.5	497	890
MSW TPP/CHPP	MW	0.0	0.0	43	118	257
MSW BG CU	MW	0.2	10	27	32	40
BG CU	MW	0.0	21	102	217	446

Table 12 – Specific capital costs and required volume of investments*

Balance item	Unit	2010	Forecast			
			2015	2020	2025	2030
Coal TPP reconstruction	€/kW_e	200	200	300	300	300
BM TPP	€/kW_e	2500	2700	3000	3200	3500
BM CHPP	€/kW_e	2300	2500	2800	3100	3300
MSW TPP/CHPP	€/kW_e	2300	2500	2800	3100	3300
MSW BG CU	€/kW_e	4000	4200	4400	4600	4800
BG CU	€/kW_e	3500	3800	4000	4200	4500
Total volume of investments over the period, including:	**mln. UAH**	**-**	**3 361**	**11 334**	**19 860**	**35 115**
Reconstructed coal TPP – Cf	mln. UAH	-	-	288	437	499
BM TPP	mln. UAH	-	866	735	1 104	869
BM CHPP	mln. UAH	-	1 238	4 829	9 153	13 650
MSW TPP/CHPP	mln. UAH	-	-	1 267	3 850	8 924
MSW BG CU	mln. UAH	-	425	791	270	358
BG CU	mln. UAH	-	832	3 424	5 047	10 816

*The growth of specific capital costs connected with implementation of more efficient equipment that has higher parameters.

The equivalent fuel consumption (**Table 13**) for the electricity generation was calculated on the basis of generated electricity volume and the specific fuel consumption. In 2020 it will be about 1 mln. tce, and in 2030 – 4.7 mln. tce. Taking into account the solid biomass potential (21 mln. tce) and the biogas potential (0.7 mln. tce), the share of the solid biomass potential use for TPPs, CHPPs and CUs will be 3.5% in 2020, and about 16% in 2030. Regarding the biogas use, it is planned to use about 17.5% of the biogas potential in 2020 and to raise its production up to 1.6 mln. tce by 2030 due to the use of corn silage.

Assessment of greenhouse gas emission reduction due to the electricity generation from biomass is based on the data on biofuels consumption as CO_2-neutral fuels, the amount of electricity production, sources of generation, and specific indicators. Averaged specific emission reduction (**Table 14**) was determined on the basis of computer models of MSW biogas TPP/CHPPs

and CUs, and biogas plants with CUs. Greenhouse gas emission base factors were determined on the basis of approved methodologies and indicators for Ukraine. Thus, a direct replacement of coal by biomass takes place in the electricity production at coal-fired power units. The biomass use leads to the reduction of greenhouse emission. In other cases, the decrease of greenhouse gas emissions is based on the methane emission reduction and the substitution of electricity from the grid. Consequently, the estimated amount of greenhouse gas emission will be about 27 mln. t CO_2 by 2030.

Table 13 – The equivalent fuel consumption for the electricity generation from biomass.

Balance item	Unit	2010	Forecast			
			2015	2020	2025	2030
Equivalent fuel consumption for the electricity production, total, including:	**Mtce**	**0.005**	**0.214**	**1.037**	**2.483**	**4.792**
Reconstructed coal TPP – Cf	Mtce	-	-	0.132	0.296	0.541
BM TPP	Mtce	-	0.065	0.124	0.236	0.327
BM CHPP	Mtce	0.005	0.115	0.505	1.256	2.411
MSW TPP/CHPP	Mtce	-	-	0.101	0.299	0.697
MSW BG CU	Mtce	-	0.011	0.036	0.052	0.067
BG CU	Mtce	-	0.023	0.139	0.344	0.749

Table 14 – Greenhouse gas emissions reduction due to electricity generation from biomass.

Balance item	Unit	2010	Forecast			
			2015	2020	2025	2030
Reconstructed coal TPP – Cf	t CO_{2eq}/tco	2.7	2.7	2.7	2.7	2.7
BM TPP	t CO_{2eq}/MWh	1.067	1.067	1.067	1.067	1.067
BM CHPP	t CO_{2eq}/MWh	1.067	1.067	1.067	1.067	1.067
MSW TPP/CHPP	t CO_{2eq}/MWh	1.067	1.067	1.067	1.067	1.067
MSW BG CU	t CO_{2eq}/tco	13.8	13.8	13.8	13.8	13.8
BG CU	t CO_{2eq}/tco	7.68	7.68	7.68	7.68	7.68
Greenhouse gas emissions reduction, total, including	**mln. t CO_{2eq}**	**0.012**	**0.672**	**3.384**	**7.802**	**15.292**
Reconstructed coal TPP – Cf	mln. t CO_{2eq}	0.000	0.000	0.356	0.798	1.462
BM TPP	mln. t CO_{2eq}	0.000	0.128	0.252	0.486	0.722
BM CHPP	mln. t CO_{2eq}	0.010	0.216	1.007	2.554	4.995
MSW TPP/CHPP	mln. t CO_{2eq}	0.000	0.000	0.201	0.608	1.444
MSW BG CU	mln. t CO_{2eq}	0.002	0.150	0.503	0.712	0.918
BG CU	mln. t CO_{2eq}	0.000	0.177	1.064	2.643	5.750

Conclusions

In order to implement the proposed Concept of biomass use for electricity generation, the relevant government authorities, state departments, state agencies, and special-purpose committees must overcome existing barriers, develop and implement the necessary mechanisms to support electricity generation from biomass. The process of improving of the updated Energy Strategy of Ukraine till 2030, its approval with a clear presentation of the set goals on RES issues and biogeneration require the urgent attention.

The proposed UABio's Concept of the electricity generation from biomass in Ukraine until 2030 is aimed at increasing of RES share in the electricity generation, including solid biomass, biogas, and liquid biofuels. Goals set till 2030 meet the general trend of the RES development in the

EU and worldwide, but the level of biomass use for electricity generation in Ukraine will be predictably lower than an average European one. The implementation of the proposed Concept will make it possible to achieve 4% of the total electricity generation in Ukraine until 2030. Moreover, the Concept will contribute to both development of the domestic market of RES production and consumption, and the increase of the country's energy independence. The development of biogeneration will help to attract private and bank capital, to develop the RES domestic market and related markets, to contribute to the creation of local jobs, to upgrade equipment and to increase its energy efficiency and environmental safety.

Abbreviation

BM – biomass;
BP – biogas plant;
Cf – co-firing;
CHPP – combined heat and power plant;
CU – cogeneration unit;
FPR – fuel and power resources;
ICUF – installed capacity utilization factor;
MSW – municipal solid waste;
RES – renewable energy sources;
TPP – thermal power plant;
UABio – Bioenergy Association of Ukraine

Previous UABIO's publications

1. Position Paper N1 "Position of bioenergy in the draft updated energy strategy of Ukraine till 2030".
2. Position Paper N2 "Analysis of the Law of Ukraine "On amending the Law of Ukraine «On Electricity" №5485-VI of 20.11.2012".
3. Position Paper N3 "Barriers to the development of bioenergy in Ukraine".
4. Position Paper N4 "Prospects of biogas production and use in Ukraine".

Civic union "Bioenergy Association of Ukraine" (UABio) was established to create a common platform for cooperation on bioenergy market in Ukraine, as well as to provide the most favorable business environment, accelerated and sustainable development of bioenergy. General constituent assembly of UABio was held on September, 25, 2012 in Kyiv. Currently, the Association is in the process of state registration. Among UABio members are over 10 leading companies and over 20 recognized experts working in the field of bioenergy.
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Bioenergy Association of Ukraine