PROSPECTS OF BIOMETHANE PRODUCTION AND USE IN UKRAINE

UABio Position Paper № 11

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25 July 2014

Discussion within UABio: from 11.07.2014 to 30.07.2014
Approval by the Board of UABio and publication at www.uabio.org: 25.07.2014
The publication is available at: www.uabio.org/activity/uabio-analytics
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ACKNOWLEDGEMENT

The authors express their sincere gratitude to all experts who actively participated in the discussion of the position paper and submitted their observations and comments. Most of the comments were taken into account in preparing the final version of the document, which significantly improved its quality.

In particular, we are grateful to:

Harry Movsesov
Yevhen Oliinyk
Maxim Sysoev

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INTRODUCTION

The prospects for the development of biomethane (BM) production are discussed in this position paper of Bioenergy Association of Ukraine. It is a new direction for Ukrainian renewable energy. The opportunity, the importance of expediency as well as recommendations for the development of production and use of biomethane in Ukraine are shown.

Biomethane under normal conditions is a gaseous fuel with a calorific value close to natural gas (NG) (35 MJ/nm^3). To date, biomethane is mainly obtained by purification and enrichment of biogas produced by biochemical methods from different types of organic materials.

Biomethane production is growing rapidly in the EU and has a good preconditions and prospects in Ukraine, namely:

1. High energy intensity of the economy of Ukraine in comparison with world figures. Unreasonably large consumption of natural gas, including the needs of backward industrial enterprises.
2. Critical Ukraine's dependence on gas supplies from unstable foreign markets, including Russia.
3. High and volatile natural gas prices, upward trend for all categories of consumers.
4. Great potential for biogas production from agricultural waste (3.2 billion m^3 CH_4 per year).
5. Large potential of biogas/biomethane production (3.3 billion m^3 CH_4 per year) using available arable fertile land for energy crops cultivation and their potentially lower cost (compared to the production in western countries).
6. Presence of significant number of big agricultural enterprises with financial and land potential for the development of major projects for biomethane production.
7. Presence of the developed NG transport infrastructure, including both pipelines connecting Ukraine with European countries, and local network of distribution pipelines, providing greater part of the population of Ukraine with natural gas.
8. Tradition of NG using as motor fuel for vehicles, well-developed network of vehicles gas filling compressor stations (VGFCS[1]).

Biomethane can be produced for both domestic consumption (feed gas distribution network, followed by use for electricity and/or thermal energy, or use as vehicles fuel) and for export (by main gas pipelines, road and railway transport or sea).

Currently in Ukraine there are no examples of biomethane production projects, as there is no legal and regulatory framework for its use. Given the prospect of this trend in the current environment of Ukraine, presented in this paper, the material could be useful and relevant to policy and investment decisions.

DEVELOPMENT OF BIOMETHANE PRODUCTION AND USE IN THE WORLD

Total primary energy production from biogas in the EU amounted to more than 12 million tonnes of oil equivalent (equivalent to 14.8 billion m^3 NG)[2] emissions in 2012. Total number of

[1] VGFCS – vehicle gas filling compressor station

biogas plants in 2014 exceeded 13,800 units[3]. According to the National Action Plan for the development of renewable energy in EU (NREAP), by 2020 is expected to produce biogas in equivalent of 28 billion m3 of NG. It is expected that the use of land resources for the implementation of the declared energy plans will not compete with production of basic food and feed stuffs.

Main direction of the biogas energy use is feeding electricity into the power grid. Intensive development of biomethane production projects, followed by injection into the NG network began in the last decade. Usually biomethane fed into the gas distribution network at a pressure below 16 bar. Examples of biomethane injection in high-pressure pipelines or gas storage facilities are not known. In some cases, BM is supplied directly to the gas filling stations for use as a motor fuel.

Biomethane production projects are geographically located in Europe, North America (USA, Canada), and the Far Eastern countries: Japan and South Korea (Fig.1).

Currently, BM is produced in 15 European countries[4]. Injection of BM in NG grid takes place in 11 countries (Austria, Czech Republic, Germany, Denmark, Finland, France, Luxembourg, Netherlands, Norway, Sweden, UK)[5]. In 12 European countries (Austria, Czech Republic, Germany, Denmark, Finland, France, Hungary, Iceland, Italy, Netherlands, Sweden, United Kingdom) biomethane used as motor fuel (separately or mixed with NG). Biomethane also used for heat production (also separately or in admixture with NG).

To date, the total number of stations in biomethane stations in European countries reached 250 units, of which 200 stations connected to the NG[6].

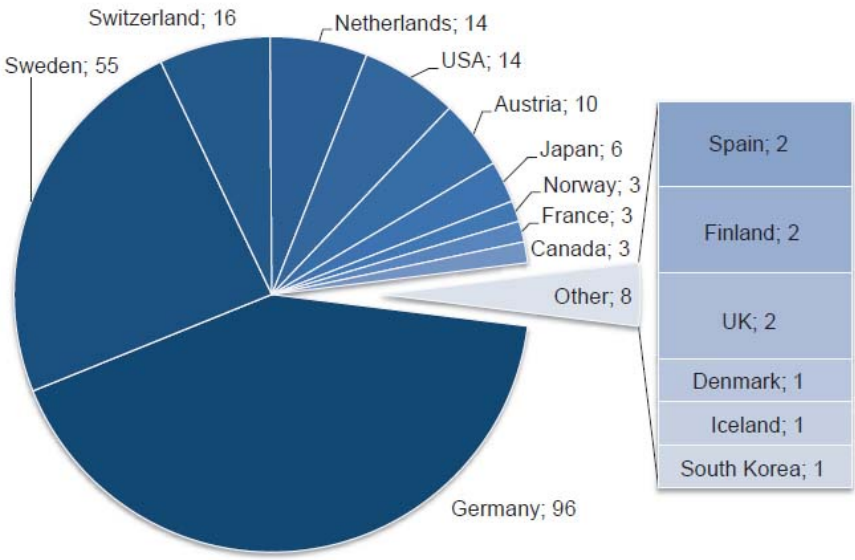


Fig. 1 – Biomethane projects in the world[7], *IEA Bioenergy Task 37, 2012*

[2] Biogas Barometer / EurObserver, 2013
[3] European Biogas Assotiation (EBA) / Press release, 15 January 2014, Nuremberg
[4] EBA's BIOMETHANE fact sheet / European Biogas Assotiation (EBA), 2013
[5] *Attila Kovacs* Proposal for a European Biomethane Roadmap / EBA, December 2013
[6] European Biogas Assotiation (EBA) Deutsche Energie Agentur (DENA), 2014
[7] *Fredric Bauer, Christian Hulteberg, Tobias Persson, Daniel Tamm.* Biogas upgrading – Review of commercial technologies / SGC Rapport 2013:270

For biogas upgrading to biomethane different technologies are used. Most common is water scrubber technology, as well as pressure swing adsorption (PSA) and chemical scrubber (Fig. 2).

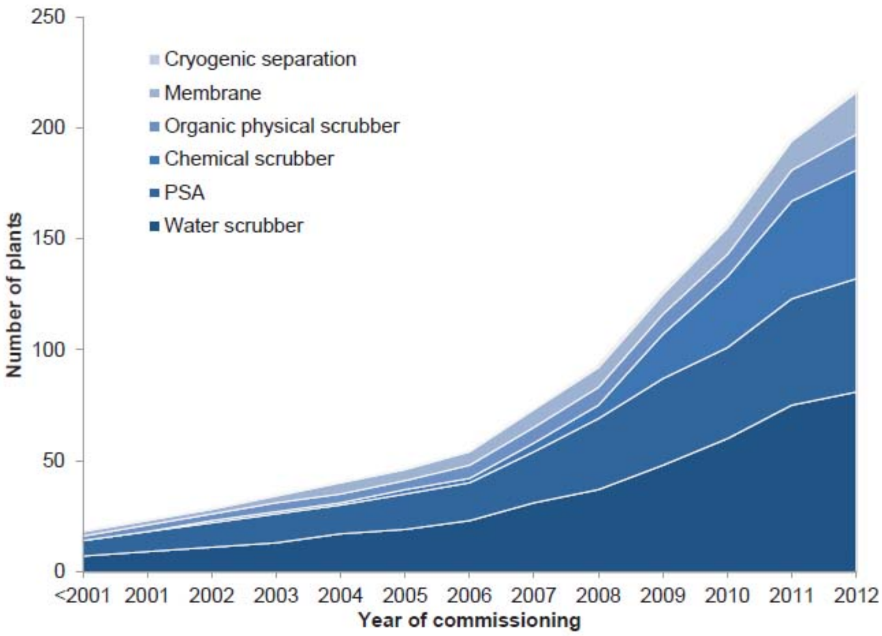
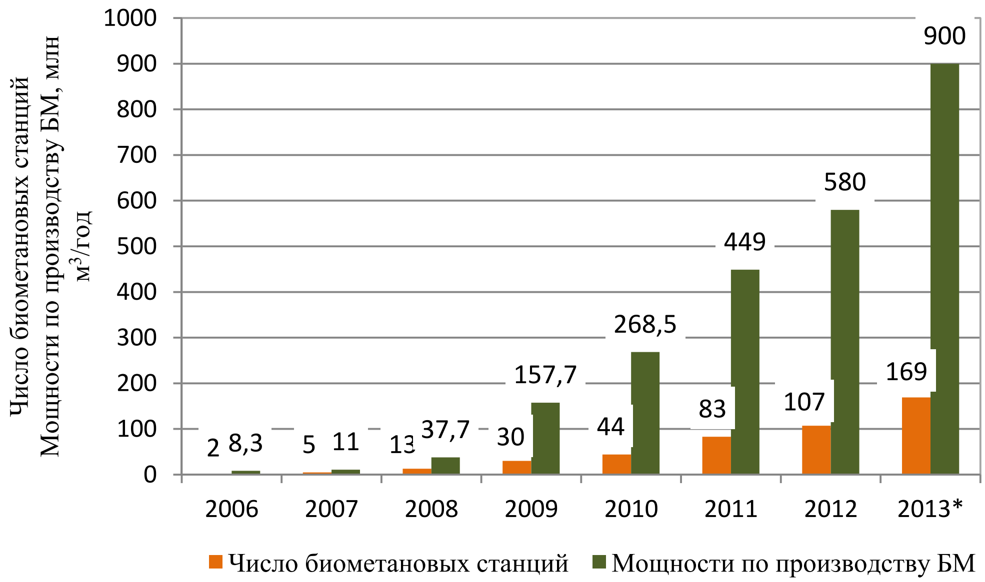


Fig. 2 – Biogas upgrading technology in the world[8], *IEA Bioenergy Task 37, 2012*

Total production of BM in 2012 was 0.76 billion m^3. According to estimates by the European Biogas Association (EBA) annual BM production in the EU could reach 8.9 billion m^3 by 2020 and 19.8 billion m^3 by 2023. According to the research of three European projects (BIOMASTER, GreenGasGrids and Urban Biogas) biomethane could replace 3% of the total NG consumption or 10% of total consumption of motor fuels in the EU. According to NGVA (Natural and bio Gas Vehicle Association), BM production from 3.5-5.4% of biogas could replace 10% of the total gas consumed as motor fuel or 0.5% of total consumption of motor fuels in the EU.

Most dynamically BM production is developing in Germany. The first BM plant began its work in 2006. During the period from 2006 to 2013 the number of BM projects grew up to 169 units. The total BM capacity increased to 900 million m^3 per year (Fig. 3) Most of the projects delivered biomethane into the NG grid, several projects provide gas filling stations. Capacity of the projects varies widely within the country. The biggest projects produce 10,000 m^3 of biomethane per hour (Güstrow, Zőrbig, Schwedt), the smallest projects generate less than 300 m^3 of biomethane per hour. Average BM capacity is around 550-600 m^3/h.

[8] *Fredric Bauer, Christian Hulteberg, Tobias Persson, Daniel Tamm.* Biogas upgrading – Review of commercial technologies / SGC Rapport 2013:270



*- prognosis by announced projects

Fig. 3 – Development of BM production in Germany[9]

Overall, in December 2013 in Germany primary energy of biomethane was used mainly for electricity (68%) and heat (31%) production.

Natural gas plays a minor role in the transport sector in Germany. Approximately 90,000 vehicles running on the country's natural gas (0.2% of the total leet). For this reason, only a small portion (1%) of BM has found an application as a motor fuel. However the number of gas filling stations is large enough accounting 900 units, although the density of gas filling network smaller than density of liquid fuel stations. There is a trend of the growing of BM use as motor fuel. Thus, during 2012, the share of biomethane for vehicles increased from 6 to 15% of the total use of gas fuel in the market.

German Federal Government has set a target to increase production of BM in 2020 to 6 billion m^3/year and in 2030 up to 10 billion m^3 per year. Goals to further increase of BM use as a motor fuel are also announced. The fulfillment of these objectives will be accompanied by increasing the number of filling stations from 900 to 1300 units and introduction of standards for the use of BM at 20% in the mixture on compressed NG.

Sweden is rightly considered as one of the leader in the use of biomethane for transport. As of 2012, there were 55 biomethane stations (BMS), of which only 11 supplied BM into the NG grid[10]. Total production of BM was about 135 million m^3 per year. With an average annual growth of BM consumption as motor fuel equals 25% the share of BM consumption in Sweden twice exceeded the share of natural gas in 2009 (Fig. 4).

[9] Bundesverband der Energie- und Wasserwirtschaft e.V., dena
[10] Svenskt Gastekniskt Center AB (SGC), 2013

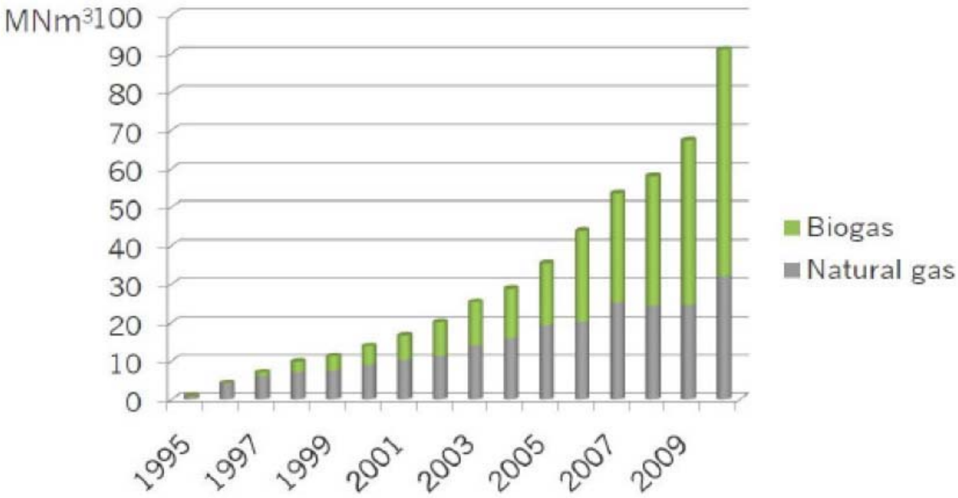


Fig. 4 – Development of gas consumption for transportation in Sweden[11]

Sweden has developed infrastructure allowing BM consuming in considerable amount. So here in 2012, there were 138 public and 57 business gas filling stations for BM. Biomethane was used by 44 thousand vehicles, including 1800 buses and 600 trucks.

For biogas upgrading in Sweden water scrubber (68.6%), less PSA (14.7%) and amine scrubber (16.7%) are mainly used.

In Switzerland in 2013 were operated 19 BMS and 135 BM filling stations. The overall performance of BMS was about 53 million m^3 per year. Well-developed infrastructure for gas motor fuel is present. The Government supports the use of both compressed and liquefied NG, there are about 10,000 natural gas vehicles and 130 public fueling stations.

The most common way of upgrading is PSA (11 stations). Chemical and amine scrubbers (three stations for both) and Organic Physical scrubber (two station) are also used.

In **the Netherlands** 21 BMS were under operation in 2012. Four stations are producing biomethane from landfill gas, 4 from sewage sludge, 10 from organic fraction of MSW and organic industry waste, 3 from agriculture biomass. All BMS supply BM in NG grid. Total BM production is 100 million m^3 per year[12]. The goal for 2020 is the production of biomethane in energy equivalent of 24 PJ (670 million m^3 CH_4).

In **Austria** there is a long tradition of producing biogas from MSW, sewage sludge and industrial waste. Besides the production of biomethane from biogas gasification technology is developing as well as research projects for the production of synthetic natural gas (bio-SNG). Pilot plant for the production of bio-SNG from wood of 120 m^3/hr capacity is launched in Güssing in 2006.

Totally there are more than 500 biogas plants (BGP) in the country. The first station producing biomethane started in 2005. Today there are 12 BMS with total capacity of approximately 24 million m^3 BM per year[13]. Most of the stations deliver BM in NG grid. In three

[11] Natural Gas for Vehicles – IGU & UN ECE Joint Report

[12] GreenGasGreeds / Netherlands / Biomethane Utilisation pathways. Доступно: http://www.greengasgrids.eu/market-platform/netherlands/utilisation-pathways.html

[13] *Günter Bochmann* / Universitet BOKU, 2013Austria

projects BM is used for directly for gas filling stations. Biomethane is utilized mainly in transport sector as well as for production of heat

In Austria, there are about 6000 vehicles using compressed natural gas, consuming about 475 TJ (2% of NG consumption). System of 170 gas filling stations is one of the most advanced in Europe. It is planned to increase the number of gas filling stations up to 200 units. NG blending system exists through the addition of 20% biomethane branded as bio-CNG.

The most common technique for the biogas purification is PSA technology (5 stations). Water and amine scrubber as well as membrane separation are used.

European projects of BM production development

The development of BM production in Europe is accompanied and stimulated by European projects, such as:

- **GreenGasGreeds.** GreenGasGrids project supports the upgrading of biogas to biomethane for injection into the natural gas grid; the project involved a consortium of 13 European partner companies, coordinated by the German Energy Agency (dena);
- **BIOMASTER**. Project is supported by 17 partner companies, aims to promote the use of biomethane in transport sector; project is also intended to promote the use of methane in the NG grid;
- **Urban Biogas**. Project is created to promote the use of biomethane in local NG network. The basic idea of the project is to develop projects of the municipal waste treatment with biomethane production in cities of five European countries (Croatia, Portugal, Austria, Poland, and Latvia).

TECHNOLOGY OF BIOMETHANE PRODUCTION

Biomethane can be produced in three main ways:

1. Microbiological fermentation of organic material with a low content of lignocellulosic complexes (LCC), mainly from agriculture raw materials and waste, the organic fraction of MSW, sewage and sludge in controlled bioreactors to produce biogas and its subsequent purification from impurities and increasing methane content;
2. Collection of biogas at landfills and waste dumps with subsequent purification from impurities and adjusting to the quality of NG;
3. Biomass Gasification (with high LCC content mostly wood) to produce synthesis gas (mixture of hydrogen, methane and carbon monoxide) with its subsequent methanization, purification and quality adjustment to NG. Gasification technology and methanation is under research and pilot projects stage.

Biogas is composed mainly of CH_4 and CO_2 (up to 98-99% in total), and impurities (0-2%). Depending on the type of raw materials and the technology biogas can differ substantially, which largely determines the technology of its upgrading to biomethane. Table 1 shows the comparative characteristics of biogas from different sources.

Table 1. Composition and characteristic of biogas from different sources[14]

Parameter	Units	LFG	Biogas from manure
Lower calorific value	MJ/nm^3	16	23
	kWh/nm^3	4,4	6,5
	MJ/kg	12,3	20,2
Density	kg/nm^3	1,3	1,2
Wobbe index	MJ/nm^3	18	27
Methane number	-	> 130	>135
Methane	vol-%	45	63
Methane, variation	vol-%	35–65	53–70
High hydrocarbons	vol-%	0	0
Hydrogen	vol-%	0–3	0
Carbon monoxide	vol-%	0	0
Carbon dioxide	vol-%	40	47
Carbon dioxide, variation	vol-%	15–50	30–47
Nitrogen	vol-%	15	0,2
Nitrogen, variation	vol-%	5–40	–
Oxygen	vol-%	1	0
Oxygen, variation	vol-%	0–5	–
Hydrogen sulfide	Ppm	< 100	< 1000
Hydrogen sulfide , variation	ppm	0–100	0–10000
Ammonia	ppm	5	<100
Total clorine (based on Cl^-)	mg/nm^3	20–200	0–5

An important difference of landfill gas is the probability of increased content of nitrogen, oxygen, sulfur, chlorine, siloxanes. In turn, biogas from agriculture waste differs by increased content of hydrogen sulphide and ammonia, siloxanes[15] are practically absent.

Various components in the biogas can differently effect on subsequent transportation and utilization of biomethane. Table 2 shows the main impurities in the biogas and the nature of their influence.

In landfill gas along with nitrogen oxygen can be taken from air infiltration through the landfill. Oxygen promotes corrosion and biofouling in gas storage facilities. Priority in the case of the production of biomethane is the maximum reduction in oxygen ingress into biogas, which is achieved by using appropriate methods as pre-treatment, and control of air intrusion in landfill gas collection systems.

Table 2. Types of admixture in the biogas from different sources and nature of their impact[16]

Admixture type	Source of origin	Impact
CO_2	Carbon mineralization of organic matter	Reduces the overall calorific value, leading to corrosion of the metal parts of the equipment due to the formation of weak carboxylic acid
H_2S	Proteins, manure, organic waste	Leads to corrosion of metal parts, SO_2 emissions from the combustion or H_2S by incomplete combustion, destroys catalytic converters
H_2O		Due to the formation of weak acids with other substances promote corrosion of metal parts; damage instrumentation from

[14] M. Persson, O. Jönsson, A. Wellinger. Biogas upgrading to vehicle fuel standards and grid injection. – IEA Bioenergy. Task 37 - Energy from biogas and landfill gas. – December 2006.
[15] Siloxanes are a subgroup of silicones containing Si-O bonds with organic radicals
[16] *Sabine Strauch, Joachim Krassowski, Ankit Singhal*. Biomethane Guide for Decision Makers – Policy guide on biogas injection into the natural gas grid / Fraunhofer UMSICHT WP 2 / D 2.3 April 2013

Admixture type	Source of origin	Impact
		airborne condensate; leads to icing accumulated moisture at high pressures and relatively low temperatures
NH_3	Proteins	Leads to an increase in anti-knock properties of the engines; causes the formation of NOx, promotes corrosion
N_2	With air	Leads to an increase in anti-knock properties of the engines; reduces overall calorific value
Silixanes	Cosmetics, defoamers, detergents (in LFG and sludge)	Because quartz silica particles leads to abrasion of moving parts
Dust	LFG	Leads to clogging in ventilation systems and chimneys

The choice of methods of biogas upgrading

There are three main reasons why upgrading of biogas is needed:

- Ensure compliance to the properties of fuel used in various types of equipment (engines, boilers, fuel cells, etc.);
- Increase caloric value;
- Standardization of gas fuels.

Methods of biogas upgrading depend on method of following utilization. For example, for heat production in the boiler restrictions apply only H_2S concentration (1000 ppm). Thus there is no need to remove moisture and carbon dioxide. In case of biogas cookers there are higher requirements for cleaning of H_2S. For biogas combustion in reciprocating engines, there are certain requirements for the content of H_2S (generally no more than 200 ppm) and siloxanes, and excessive moisture content (no condensation allowed). The most stringent requirements for biogas cleaning imposed in the case of supply to NG grid and direct use as a motor fuel. In this case it is necessary to upgrade biogas to NG quality.

Methods of biogas upgrading

The main target component for removal in biogas upgrading is carbon dioxide. Technology for its removal is crucial in the overall scheme of purification. Additional purification steps are pre- or post-removal of impurities, mainly H_2S, moisture, siloxanes, and possible correction of BM to the dew point temperature and the calorific value depending on the requirements of the applicable standard. An important component of the scheme is to clean flue gas discharge to the atmosphere.

Biogas enrichment sorption, filtration and cryogenic techniques are main parts of the used technologies. There are 6 major commercial technologies of biogas upgrading:

- Pressure swing adsorption (PSA).
- Absorption of water (water scrubber).
- Organic physical scrubber
- Chemical scrubber.
- Membrane separation.
- Cryogenic separation.

Pressure swing adsorption

The essence of the method consists in sorption of CO_2 molecules on the surface of materials under high biogas pressure. Activated carbon or molecular sieves are usually used as sorbent material. The process removes also O_2 and N_2. Regeneration held by stripping under reduced pressure. In this method, moisture and the H_2S should be removed at the preliminary stage.

Water scrubber

Solubility CH_4 in water is lower by factor 25-74 than solubility of CO_2 and H_2S, respectively ($P = 101.325$ Pa, $T = 20°$ C) [17,18,19]. This physical feature is the basis of the method of gases separation by absorption in the water scrubber at elevated pressure (5-10 bar). Desorption of CO_2 and H_2S from the water takes place when the pressure reduces to atmospheric pressure or lower. To intensify desorption the air is used. To prevent fouling of water circulation system it is recommended to remove H_2S in the preliminary stage. Water vapor is removed after the upgrading stage. A feature of this technology is the need to control the content of O_2 after air stripping.

Organic physical absorption

Some organic substances capable of absorbing CO_2 and H_2S more active than water. As such adsorbent usually used polyethylene glycol (e.g., trademarks Selexol® and Genosorb®). Basic processes for this case are similar to the water scrubber technology. Hydrogen sulfide is recommended to remove at a preliminary stage, since the organic sorbent regeneration requires a significant amount of energy.

Chemical scrubber

Other organic substances have the ability selectively bind CO_2 at low pressure. In chemical scrubber group of amines (monoethanolamine, dimethylethanolamine) are used. This method has a high degree of removal of CO_2 with little loss of CH_4. Regeneration of the sorbent takes place by the reverse chemical reaction is usually initiated by heating and/or vacuuming. Hydrogen sulfide is removed in a preliminary step. After upgrading, biomethane dried and compresses.

Membrane separation

Membrane separation is of two basic types: "gas-membrane-gas" ("dry" membrane) and "liquid-membrane-gas" ("wet" membranes). Dry membranes are based on the creation of a pressure difference on both sides of the membrane, wherein the gas molecules (CO_2 and H_2S) pass through the membrane pores, and CH_4 molecules do not. Dry membranes operate at high (> 20 bar) or medium pressure (8-10 bar). In case of wet membranes absorbents (amines) absorbing CO_2, which diffuses through the membrane are used. The process takes place in low excess pressure close to

[17] *R. Crovetto*, Evaluation of Solubility Data for the System CO2-H2O, J. Phys. Chem. Ref. Data, 20, 575, 1991.
[18] *P. G. T. Fogg and C. L. Young, Eds*., IUPAC Solubility Data Series, Vol. 32, Hydrogen Sulfide, Deuterium Sulfide, and Hydrogen Selenide, Pergamon Press, Oxford, England, 1988.
[19] H. L. Clever and C. L. Young, Eds., IUPAC Solubility Data Series, Vol. 27/28, Methane, Pergamon Press, Oxford, England, 1987.

atmospheric. Before upgrading biogas is compressed and dried. After separation requires additional cleaning from H_2S.

Cryogenic separation

The boiling temperature of methane is -161,5 ° C, and carbon dioxide -78,5 ° C. With decreasing temperature and overpressure condition CO_2 becomes liquid when methane is still in gaseous. In this CO_2 can be relatively easily separated from the methane. CO_2 in this case is sufficiently pure and can be used as commercial product. Moisture and hydrogen sulfide should be removed in advance.

Removal of hydrogen sulfide (H_2S)

For H_2S removal biological, chemical and physico-chemical methods are used. In biochemical desulfurization excessive amounts of O_2 and N_2 can stay in biogas that should be considered when selecting the technology of biomethane upgrading. In this regard, other techniques such as the catalytic conversion of the sulfur in the surface of the activated carbon or the exchange reaction with the oxide/iron hydroxide to form FeS, in some cases more preferred.

Removal of oxygen (O_2) and nitrogen (N_2)

In biogas enrichment technologies such as PSA and membrane separation, oxygen and nitrogen, to a certain extent removed simultaneously with CO_2.

Dewatering

Biogas after reactor or landfill has a relative humidity of 100%. Water vapor content depends on temperature and equals 40 g/nm^3 at 35^{o}C. A typical way of removing moisture from the biogas is vapor condensation at low temperatures. To raise the temperature of "dew point" before cooling further increases the pressure of biogas.

In case of biomethane use as motor fuel "dew point" should be below -40°C under a pressure of 4 bar. In this case, further water vapor adsorption on the surface of a drying agent (silica or alumina) is used. The adsorption is carried out at overpressure, after which the drying agent is regenerated when the pressure decreases.

Another way to reduce "dew point" may be the absorption of water in the glycol or hygroscopic salts. Desorption of the water occurs at higher temperatures. Salt should be replaced.

Siloxanes removal

Siloxanes removed by activated carbon. Carbon cannot be recovered and requires replacement. Another method is absorption in a liquid solution of hydrocarbons.

Table 3 shows the comparative characteristics of upgrading technologies discussed in terms of biogas needs in energy and material resources, as well as the main process parameters.

Table 3. Comparison of biogas upgrading methods[20]

		PSA	Water scrubber	Organics physical scrubber	Chemical scrubber	Membrane separation	Cryogenic separation
Electricity demand	kWh/nm^3 of biogas	0,2-0,25	0,2-0,3	0,23-0,33	0,06-0,15	0,18-0,25	0,18-0,33
Heat demand	kWh/nm^3 of biogas	0	0	~ 0,3	0,5-0,8	0	0
Temperature	°C	-	-	55-80	110-160	-	-
Pressure	bar	4-7	5-10	4-7	0,1-4	5-10	
Methane loss	%	1-5	0,5-2	1-4	0,1	2-8	
Flue gas cleaning (Requirement of EEG and GasNZV standards)		yes	yes	yes	no	yes	yes
Additional H_2S cleaning		yes	no	no	yes	recom.	yes
Water consumption		no	yes	no	yes	no	no
Chemical reagents consumption		no	no	yes	yes	no	no

Comparison of energy efficiency of biogas upgrading methods

Estimation of total energy consumption for the biogas production and upgrading shows that the energy efficiency is from 60 to 66% (Fig. 5) for different upgrading technologies. Thus, water scrubber, PSA and membrane separation are more efficient techniques. Chemical scrubber is less energy efficient due to additional heat consumption in sorbent regeneration process.

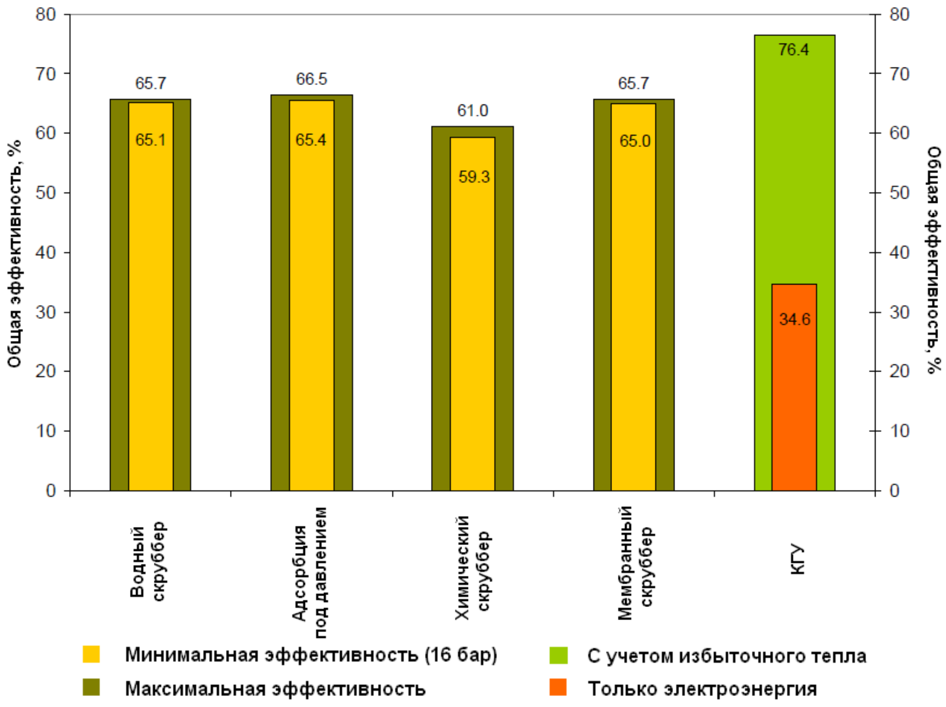


Рис. 5 – Comparison of biomethane production energy efficiency and electricity and heat production in CHP[21]

[20] Biomethane / FNR, 2013
[21] DWGW, 2010

In the case of energy production from biogas in CHP the total energy efficiency in the absence of the heat consumer (typical case in practice) is limited by electrical efficiency of IC-engine and does not exceed 35-40%. Therefore, biogas upgrading to biomethane, followed by the most complete utilization of its energy can be considered as a priority in terms of efficient use of resources (such as raw materials and energy). In turn, the most complete utilization of biomethane energy is possible while minimizing losses during transportation and final consumption. Production of electrical energy from the biomethane without heat recovery seems irrational.

Biomethane quality standardization

Most of the existing standards for biomethane developed in European countries and regulate its properties for injection in NG grid. Standard for biomethane as a motor fuel is used only in Sweden (SS155438: 1999). Table 4 illustrates the comparative requirements of national standards for the composition of biomethane in several European countries.

Table 4. Requirements of national standards for the composition of BM[22]

Component	Unit	**Austria** a)	**France**	**Belgium**	**Czech Republic**	**Germany**	**Netherlands**	**Sweden**	**Switzerland**
CH_4	% vol.	≥ 96	≥ 86	≥ 86	≥ 95		≥ 85	≥ 97	≥ 96
CO_2		≤ 3	≤ 2,5	≤ 2,5	≤ 5	≤ 6 (dry)	≤ 6	≤ 3	≤ 6
O_2		≤ 0,5	≤ 0,01		≤ 0,5	≤ 0,5 (wet), 3(dry)	≤ 0,5	≤ 1	≤ 0,5
H_2		≤ 4	≤ 6	≤ 0,1		≤ 5	≤ 12 (0,5)	≤ 0,5	≤ 4
CO			≤ 2	≤ 0,2			< 1		
S total	mg/nm^3	≤ 10	≤ 30	≤ 30	≤ 30	≤ 30	≤ 45 (16,5)	≤ 23	≤ 30
H_2S (+COS in France and Belgium		≤ 5	≤ 5	≤ 5	≤ 7	≤ 5	≤ 5	≤ 10	≤ 5
Mercaptans		≤ 6	≤ 6	≤ 6	≤ 5	≤ 15	≤ 10 (6)		≤ 5 ppmV
Halons		0	≤ 1 (Cl) ≤ 10 (F)	≤ 1 (Cl) ≤ 10 (F)	≤ 1,5 (F+Cl)	0	≤ 50/25 (Cl/F)		≤ 1
Heavy metals			≤ 1 (µg, Hg)	≤ 1 (µg, Hg)		≤ 5			≤ 5
Siloxanes		≤ 10			≤ 6 (Si)		≤ 5 ppm = 6.2 (Si) (0.08 (Si))		
Ammonia		Tech. absent	≤ 3	≤ 3	No		≤ 3	≤ 20	≤ 20
H_2O				≤ 110				≤ 32	
Water dew point	°C	≤ -8, 40 bar	≤ -5, P_{max}		≤ -10	Ground temperature	≤ -10, 8 bar (≤ -8, 70 bar)	≤ t_{min}-5	Co condensate
Odorant		By demand	15-40 mg THT/m^3			By demand	>10, 18-40 mg THT/m^3		
Particles		Tech. absent	Tech. absent		No particles	No particles	Tech. absent	≤ 1 (µmol)	

Designation: a) - OEVGW G31 / G33;

[22] *Mattias Svensson*. Biomethane standards. Gas quality standardization of biomethane, going from national to international level / European workshop Biomethane, Brussels 11 March 2014

It is evident that the quality requirements for biomethane vary widely from country to country. For example, in the Netherlands and France, the content of CH_4 in the biomethane can be lowered to 85 and 86%, respectively. In Sweden, the content of CH_4 in biomethane must be greater than 97%.

PROMOTION OF BIOMETHAANE PRODUCTION IN EU

State support is an effective stimulus of BM production. However present support schemes in Europe are mainly aimed at the generation of electricity. At the national level, only a few Member States set specific goals for the production of biomethane and methods of achieving them. Below is a brief description of the mechanisms for stimulating BM production in the leading countries in this field by information published in the report[23].

Germany is a leader in the development of biogas technology in Europe. The main raw material for the production of biomethane is maize silage. This is typical for large projects. Manure is typical for small biogas plants producing electricity from biogas. The new German Act on RES, enacted in 2012, limits the proportion of maize silage and crops residuals use for the production of biogas/biomethane is not more than 60%. Simultaneously document stimulates the use of biodegradable household and industrial waste as well as pasture grasses. German law supports co-production of heat and electricity, so most of the produced BM used by CHPs.

Requirements for connection to the gas network (GasNZV) describe the general conditions of access for biomethane plants, in particular:

- Procedures - how to submit and execute requests for grid connection.
- The dividing of responsibility and connection costs.
- Regulation of methane leaks.
- Providing a special bonus for non-use of main pipelines, equal 0,7 €cent/kWh.

In general, the document defines the basic cost-sharing between the producer and the owner of NG network (25%/75%). If the distance between the biomethane station and the point of connection to the grid is less than one kilometer, the cost for BM producer is limited by €250,000. If the distance is more than 10 kilometers, the costs are fully covered by the producer. Connection point is the property of the grid owner. The cost of its operation, the pressure rise, odourization, monitoring and possible correction of BM calorific value are covered by the owner. The owner is required to ensure the 96% technical readiness of the connection point for the year.

Requirements for BM quality are described in the technical standards DVGW G260 and G262. Standards include two possibilities for BM injection - as an additional gas, and as a substitute of NG. In the first case the gas mixture in the pipeline must comply with the technical requirements, so the network can accept different quality of biomethane, especially in large pipelines.

Demand for biomethane Germany is formed by the following factors:

- Fixed tariff for renewable electricity.
- Commitments for production of renewable heat.

[23] Overview of biomethane markets and regulations in partner countries. – GreenGasGreed. – March 2012.

- Commitments for production of renewable motor fuel.

Producers of renewable energy in Germany are guaranteed in access to the electricity grid and a fixed tariff rate for 20 years. Production of electric energy from biomass can qualify for a fixed rate only in case of heat use (CHP). All buildings constructed in Germany after 01/01/2009 must use renewable energy for heating. In the case of BM at CHP a share of renewable fuels must be at least 30%.

Since 2007, all suppliers of motor fuels must use a certain percentage of biofuels in petrol and diesel fuels. In 2009, biomethane has got equal rights with liquid biofuels. In the case of non-compliance, for example, the owner of the gas station has to pay fines. Conversely, an excess of liabilities can be sold on the market.

To participate in the support schemes biomethane producers and consumers should confirm the source of its origin and compliance with certain criteria. For this purpose, the Agency dena has developed German biogas register, introduced in 2011. Register defines BM standards and allows manufacturers, retailers and consumers to document the type of biomethane. According dena market accepts a documentation system and most of the produced biomethane goes throw the register.

Sweden is a pioneer of upgrading of biogas to biomethane, developing this technology over the last twenty years. Most of biomethane in Sweden is used as motor fuel. Approximately half of the Swedish biomethane plants works based on wastewater treatment plants. The rest uses MSW and agriculture waste for biomethane production. Sweden has a significant potential of bio-SNG production from forest residuals, so the government supports gasification research projects, the most famous of which is the project in Gothenburg (GoBiGas) for the production of biomethane with capacity 80 MW (8000 m^3/h of BM). According to the decision of Parliament contribution of RES in final energy consumption should reach 50% in 2020. This goal has been achieved already in 2012. Sweden is considering the full transition to renewable energy sources by 2050. It is assumed that in 2030 the transport sector will not be dependent on fossil fuels.

Sweden has developed network of natural gas supply. The first terminal for liquefied natural gas (LNG) was built in May 2011. Using LNG is considered as a link between natural gas and biomethane/biogas required until the possibility of using liquefied biomethane / biogas (LBG) will be developed.

Biomethane in transportation sector has been used since 1996. The market share of the compressed NG for transport has risen steadily, and the use of biomethane increased overtaking pace. Approximately 15% of buses in Sweden running on biogas, and the proportion of new buses on biogas reaches one-third. At the city level different incentive mechanisms are used like exemption from payment for entrance into the city, special lanes for BM taxi, free parking for BM car.

Standard SS 155438 "Motor fuel - biogas as a fuel for high-speed Otto engines Otto" was developed in Sweden in 1999. It is also used in the case of injection into the gas network. The standard requires that the methane concentration should exceed 97%, determined limits for the dew point, content of sulfur and other impurities. Quality of gas for injection into the network is also subject to negotiation with other European countries. It is likely that in the future more attention will be paid to the presence of traces of heavy metals, siloxanes, etc.

Use of biomethane for transportation in Sweden is stimulated by the following measures:

- Exemption from energy and carbon tax for CO_2-neutral fuels, oils/fats of vegetable and animal origin, biomethane as a fuel (since 1991).
- Government Directive of the acquisition of environmentally friendly vehicles (since 2005).
- Commitment to the sale of at least one type of renewable fuel (since 2006).
- Exemption for 5 years from the environmental tax for vehicles with emissions below 120 g CO_2/km (since 2010).
- Redaction by 40% income tax for environmental vehicles using electricity or biogas (from 2010 to 2012).

There are constantly working successive investment programs to facilitate long-term investment in municipal projects resulting in the reduction of greenhouse gases emission as well as contributing to the production, distribution and use of biogas/biomethane.

In **Switzerland** biomethane use as a vehicle fuel is encouraging. The mixture of NG and BM are sold at gas filling stations branded "Naturgas" or "Kompogas". Many local companies offer biogas to private consumers for heating purposes.

In 2011, the Parliament adopted the decision to abandon nuclear energy development and decommissioning of spent nuclear units until 2030. As a result of this decision the policy on renewable energy was changed. In particular, biogas/biomethane is regarded as an important component of energy supply. Biomethane production is supported by a special biogas fund whose objective is a 6 time increase in the production of biomethane for 6 years.

The country provides equal opportunities for access to the gas network for all types of biogas. The Standard G13-09 defines the requirements for gas quality. The Standards G11 and G209 define the procedure of odorisation and technical solution to connect to the network. The possibility of mixing biomethane with propane or LPG for correction of calorific value is also described.

In Switzerland, advanced system of fixed tariffs for electricity produced from biogas/ biomethane is implemented. The basic rate is between 14.6 to 23,3 €cents/kWh. There are requirements for minimal performance, as well as additional bonuses for heat utilization. Biogas plant using agrarian waste and no more than 20% of additional substrates (energy crops or organic waste) may receive an additional bonus 3.7 €cents/kWh with installed capacity of less than 5 MW and 15 €cents/kWh with installed capacity less than 50 kW. Upgrading of biogas to biomethane is not accompanied by additional bonuses. Fixed tariffs are guaranteed for 20 years. Unlike other forms of renewable energy, electricity tariffs from biogas/biomethane not revised downward. It is believed that the decrease in technology costs is compensated by the increased cost of raw materials for the production of biogas.

In the case of biomethane use as motor fuel special tariffs is not applied, however, BM may be exempted from paying fossil fuels tax. This takes into account technology and type of substrates, the degree of GHG emissions reduction, the risk of biomethane leakages.

In the **Netherlands**, the network is permitted for injection of BM derived from any type of biogas. One of the conditions is the lack of pathogens in biomethane. It is mandatory the use of HEPA filters and fulfillment of monitoring (at least two times per year). Calorific value of NG in the Netherlands is lower than in other countries. Accordingly methane content requirements are less stringent.

Production of renewable energy in the Netherlands is stimulated by a special scheme SDE +, which provides subsidies to cover the difference between production costs and energy prices. There were five categories of subsidies ranging from 0,483 to 1,035 €/m^3 in 2012. Tariffs are guaranteed for 12 years, but may be adjusted annually according to the market price of NG.

The country adopted national obligation for the use of motor biofuels of 10% in 2020, which also applicable to gas biofuels. Control scheme for sustainable production of biofuels is developed and implemented. The system of certification of production and consumption of BM and the raw materials used to its production was completed in 2009.

In **Austria**, the Gas Act (GWG) describes the framework conditions of injection of biomethane into the gas network. Act ensures nondiscrimination and priorities for gases of biological origin. Operators of gas distribution networks are required to define the technical conditions for connection, and the connection cost should be borne by BM supplier. Requirements for biomethane quality are described in detail in the directives ÖVGW G31 and G33 and rigidly adhered to the quality of NG. In addition to the injection process odorisation requirements must be fulfilled in accordance with Directive ÖVGW G79.

Support of biomethane production in Austria can be implemented by two mechanisms - providing federal grants and exemption of biomethane from fossil fuels tax. Grant size can reach 25% of the investments cost. Grant does not depend on the project size, the raw materials used or BM utilization option. Additionally, a bonus of 5% may be given in the case of meeting of sustainability criteria (reducing greenhouse gas emissions by 45%).

In the **UK** about 360 biogas plants were built, mainly in wastewater treatment plants. Biogas plants work also in agriculture. National strategy is focused on the processing of biodegradable waste, the use of energy crops for biogas production is limited. Currently there are two installations for the production of biomethane launched in 2010. Both projects are connected to the gas network.

It is assumed that biogas and biomethane especially will play a big role in increasing the share of renewable energy in the national energy balance. As one of the possible scenarios is considered the injection of 7 TWh (700 million m^3) of biomethane into the network in 2015, but this goal has not been adopted as mandatory.

The country has provided an equal access to the network for any gases of biological origin, including from sewage sludge and landfills. Feature of the UK is the high calorific value of NG in the network (39.0-39.5 MJ/nm^3). For this reason, the BM injection process must involve large amount of propane or LNG.

In the UK there are several mechanisms to support the production and use of renewable energy in general and BM in particular:

- Promotion of renewable heat use (RHI).
- Liabilities of renewable energy use (RO).

- Fixed (feed-in) tariffs (FITs).
- Obligation for renewable motor fuel use (RTFO).
- Exemption from climate tax (LECs).

As part of renewable heat (RHI) support delivery of any gas from biomass (AD, bio-SNG), except biogas from MSW, received the premium in the amount of 6.8 pence per kWh in addition to the price of NG. Premium is fixed for 20 years with the possibility of indexing for inflation.

Obligation for renewable energy use (RO) assumed an increased share of renewable energy every year. Scheme ensured by certificates (ROCs) having a market value, and provides an effective mechanism to stimulate the development of large projects (> 5 MW).

Using fixed tariffs (FITs) is more effective for relatively small projects (<5 MW) and involves the provision of premium from 9.4 to 14 pence per kWh depending on the size of the project over the market price for electricity. FITs and ROCs cannot be used simultaneously, but each of these mechanisms can be combined with RHI.

Obligation for the use of renewable motor fuel (RTFO) involve the use of a certain percentage of biofuels by each seller. Biomethane satisfies the requirements of RTFO.

Exemption from climate tax (LECs) relevant in the production of electricity and heat using biogas or biomethane, during which the right to receive climate certificates obtained, having a market value.

In **France** there were about 300 biogas projects in 2011, of which 71 projects on landfills, 66 based on industrial waste, 74 on sewage sludge. To date, biomethane from three stations is used as motor fuel. One pilot project is connected to the gas network.

The country has more than 13,000 vehicles using NG, mainly municipal buses and garbage trucks. There are approximately 140 gas filling stations, but only 32 of them are available to all consumers.

France has committed itself to produce 555 thousand tons of oil equivalent of biogas and install at least 625 MW of biogas by 2020. It is believed that biomethane is part of these commitments, although biomethane is not mentioned.

Biomethane can be supplied to the gas network if it meets the specifications AFG B562-1 for distribution pipelines and B562-2 for main pipelines. BM has the right to priority access to the grid. France is one of the few countries that have established a fixed rate (feed-in tariff) [24] for biomethane (Decree 2011-1597, November 2011). Rate depends on the scale of the project and determined individually. For producers of biomethane with capacity less than 50 m^3/h rate is 9,5 €cents/kWh HHV[25] (950 €/1000m^3CH_4), for more than 350 m^3/h rate is 6,4 €cents/kWh HHV (640 €/1000 m^3CH_4). Rate does not depend on the method of BM use. In addition, the tariff accounted for the amount of investment, the cost of connecting to the network, operating costs and the cost of biogas purification. Rate is reviewed annually.

In addition to fixed tariffs there is the possibility of direct subsidies from the French Environment Agency funds (ADEME), EU funds and subsidy schemes of regional councils.

[24] In Ukrainian practice such tariff named "green tariff"
[25] High Heating Value

Development of national registries of BM production

For some countries, which include and Ukraine, BM production prospects may depend on the ability of its exports. Cross-border BM trade may be developed if BM will be distributed on the incentives that apply in the domestic market of the importing country. It means that exported BM must meet the requirements of the importer. This fact must be confirmed by a competent national authority/registry in accordance with the rules agreed between the two countries. Creating a national/domestic registries of BM can be an important tool to support the BM production and cross-border trade. Implementation of registers should contribute to ensuring a reliable, transparent and independent accounting and confidence to the international market.

Currently, the EU developed an Action Plan for the development of BM production. The first stage is to develop national BM registries. In the second step cooperation between national BM registries should be developed. Functioning of the international BM market depends on the transparent and efficient system of information exchange between national registries. Cooperation and coordination between registries is essential for the future of free cross-border trade in Europe.

POTENTIAL AND POSSIBILITIES OF BIOMETAHNE PRODUCTION IN UKRAINE

The total potential of biogas production from agricultural waste, food processing industry, MSW, wastewater utilities and industrial enterprises in Ukraine at the present level of production and consumption is estimated at 3.2 billion m^3 CH_4 per year. Another 3.3 billion m^3 CH_4 can be obtained by growing energy maize (or other energy crops) at 1 million ha (3% of the total arable land in Ukraine). More detailed information about the resource base and the potential for biogas production are given in UABio position papers #4 and #9[26].

Raw materials for production of BM biochemically relatively similar. Thus for production of BM is preferable to use the raw material, quality of biogas from which can simplify and reduce the cost of biogas upgrading. For example, to prevent excessive concentrations of hydrogen sulphide in the biogas should be possible to use fewer substrates with high protein content. Another limitation may be the collection of landfill gas with a high content of oxygen and nitrogen. Further biogas upgrading to the BM may be technically not feasible, or at least not economically feasible.

Additional possibilities of BM production is associated with thermochemical gasification and methanation techniques to the production of synthesis gas and biomethane from lignocellulosic feedstock (wood biomass). As an example in Table 5 is presented an estimate of the theoretical potential for biomethane in Europe, made in the project GreenGasGrids.

It can be seen that total potential of wet biodegradable waste utilized by biochemical methods in Europe equals 26 billion m^3. Potential of woody biomass is 2.5 times higher, but its implementation is associated with the use of thermochemical gasification and methanation methods, the development of which is still at the stage of research and demonstration projects. Finally, the greatest amount of biomethane can be obtained as a result of the cultivation and processing of

[26] Доступно по ссылке: http://www.uabio.org/ru/activity/uabio-analytics

energy crops. However, this potential is determined by the strategy of land resources use and the possible competition among food, feed and energy crops cultivation.

Table 5. Theoretical potential of biomethane production in Europe[27]

Feed stock	Billions nm^3	%
Wooden biomass	66	43,7…26,8
Green mass (grass)	11	7,3…4,5
Wet waste	26	17,2…10,6
Energy crops	48…143	31,8…58,1
Total	151…246	100,0

POSSIBILITIES OF BIOMETAHNE USE IN UKRAINE

Projects scale

Biomethane production projects tied naturally to biogas project. For this reason, the possibility of biomethane project implementation depends on the availability of biogas raw materials in the area of the proposed implementation. Thus, biomethane station with capacity of 100 m^3/h of original biogas can be realized, for example, based on big farm with 25 thousand heads livestock. Similar project involving co-digestion of swine manure with maize silage can be implemented on pig farm with 14 thousand heads with the admixture of 70% silage (based on the dry organic matter). Cultivation of the desired amount of silage in this case would require 200 hectares of land.

It should be noted that only a small amount of Ukraine food enterprises and farms (up to 2% of total number) could arrange BM projects with production capacity of 100 m^3/h of biogas or more based on own waste. This amount is limited by large poultry farms, sugar plants and distilleries. Ability to implement large-scale projects (2000 m^3/h of biogas and more) is limited to single enterprise examples. In this regard, successful projects could deal with mutual waste digestion of several companies and/or energy crops. Massive increase in the biomethane production requires intensive use of agricultural land for energy crop cultivation.

The use of natural gas in Ukraine

Prospects for BM use is largely related to the level of NG consumption and the need for its substitution. The share of natural gas consumption in Ukraine is unreasonably high. It is about 43%, which is almost 2 times higher than, for example, in the EU. The bigger consumers are metallurgical and chemical enterprises. They consumed more than 18.3 billion m^3 of NG in pre-crisis 2007 that is more than 70% of consumption in the industrial sector, and over 26% of the national total. Metallurgical industry in the future would be likely to limit gas consumption to 5- 5.5 billion m^3 per year. In the chemical industry, gas consumption can be reduced by 20% to 6.8-7.2 billion m3 per year. Similar ability to reduce NG consumption exist in other industries. In 2007, industrial consumers without metallurgists and chemists used nearly 7.5 billion m^3 of NG. This figure in the near future may be reduced to 6- 6.5 billion m^3/year. Finally, consumption for NG

[27] "European Biomethane Potentials" presentation by Daniela Thrän on the GGG Workshop on 21. February 2012 in Brussels www.greengasgrids.eu

transportation decreased in recent years due to the modernization of "Ukrtranshaz" capacities, installation of new gas turbines, reducing losses to 6.6 billion m^3/year.

Population and the district heating network is large consumer of NG. Structure of NG consumption in Ukraine is shown in Table. 6. Ukraine covers NG consumption by local gas production by less than 40%, which makes the task of his substitution, including biogas and BM, especially relevant.

Table 6. Natural gas consumption in Ukraine[28], billion m^3

	2007	2009	2010	2011-2012	2020
NG transportation system own needs	7.2	5.4	6.6	6.7	6.5
Population	16.9	16.8	17.0	17.0	14.5
Teplokommunenergo	10.5	9.3	8.3	9.0	8.0
Budget organizations	1.0	0.7	0.7	0.7	0.6
Power production	8.4	3.7		3.7	3.5
Industry	25.8	16.0	23.8	23.8	18.5
– metallurgy	9.8	5.0		8.5	5.5
– chemistry	8.5	4.7		8.0	6.5
– other	7.5	6.3		7.3	6.0
Total consumption	**69.8**	**51.9**	**57.1**	**60.9**	**51.1**

Natural gas grid

Ukraine is located at the intersection of gas and oil transmission lines of European and Asian continents and thus plays a specific role in the fuel and energy markets in Europe. Unified gas transportation system of Ukraine (UGTS) consists of the main gas pipelines and distribution networks, underground gas storages and other facilities and structures intended for transportation, distribution and storage of NG. UGTS includes 39,800 kilometers of pipelines, including 14,000 kilometers of large diameter pipes (from 1020 to 1420 mm), 74 compressor stations with a total capacity of 5450 MW and 13 underground storage facilities. Input capacity of gas transport system is 288 billion m^3/year, output – 178,5 billion m^3/year

Main gas pipelines designed to transport natural gas produced from the area of extraction facilities to the point of consumption, and to transport gas from Russia to Europe. The structure of the main gas pipelines include[29]:

- Gas pipes from the exit from gas field or place of gas preparation to the distribution point or pressure reducer to 1.2 MPa;
- main and intermediate gas compressor stations (GCS);
- underground gas storage (UGS);
- gas distribution stations (GDS);
- gas treatment station (GTS) on the linear part of the gas pipeline;
- auxiliaries.

Main pipelines build up to 1420 mm diameter. Pipelines designed for a maximum pressure of 7.5 MPa, which occurs after the compressor stations. The gas pressure decreases along the pipe up to 4.3 MPa before next compressor station. Intermediate compressor stations are located

[28] http://first-drilling.com.ua/article/article_item/655

[29] «Правила технічної експлуатації магістральних газопроводів» затверджені наказом ДК "Укртрансгаз" від 20.09.2000р. № 209

approximately each 150 km. Own storage capacity of main gas transportation system from the gas fields to consumers is quite small. Underground gas storage facilities are used to cover seasonal fluctuations in consumption.

Differentiation of NG of Ukrainian and Russian origins is not exist. Own gas from gas fields pumped directly to UGTS. Imported natural gas from Russia enters by 22 gas pipes. NG is transported by 15 main gas pipes outside Ukraine.

Fig. 6 – Unified gas transportation system of Ukraine (UGTS)

Gas distribution networks are used for the distribution of NG from GDS directly to consumers. The structure of the gas distribution networks include:

- Gas system of settlements (gas pipelines, distribution pipelines, internal pipelines and inlets), the gas line to the enterprises, thermal power plants (TPP) and boiler;
- Pipelines belonging to industry, thermal power plants, boilers, utilities and public services, residential and public buildings;
- Gas control points (GCP).

Distribution pipelines divided into four categories depending on the pressure:

- high-pressure gas pipelines of Category I - at the working gas pressure of 0.6 to 1.2 MPa;
- high pressure pipelines II categories - operating at a pressure of from 0.3 to 0.6 MPa;
- medium pressure gas pipeline - with an operating pressure of from 0.005 MPa to 0.3 MPa;
- low-pressure pipelines - at a working pressure up to 0,005 MPa.

Connection between the various pipelines pressure through GDS. Example of settlement gas supply system is shown below

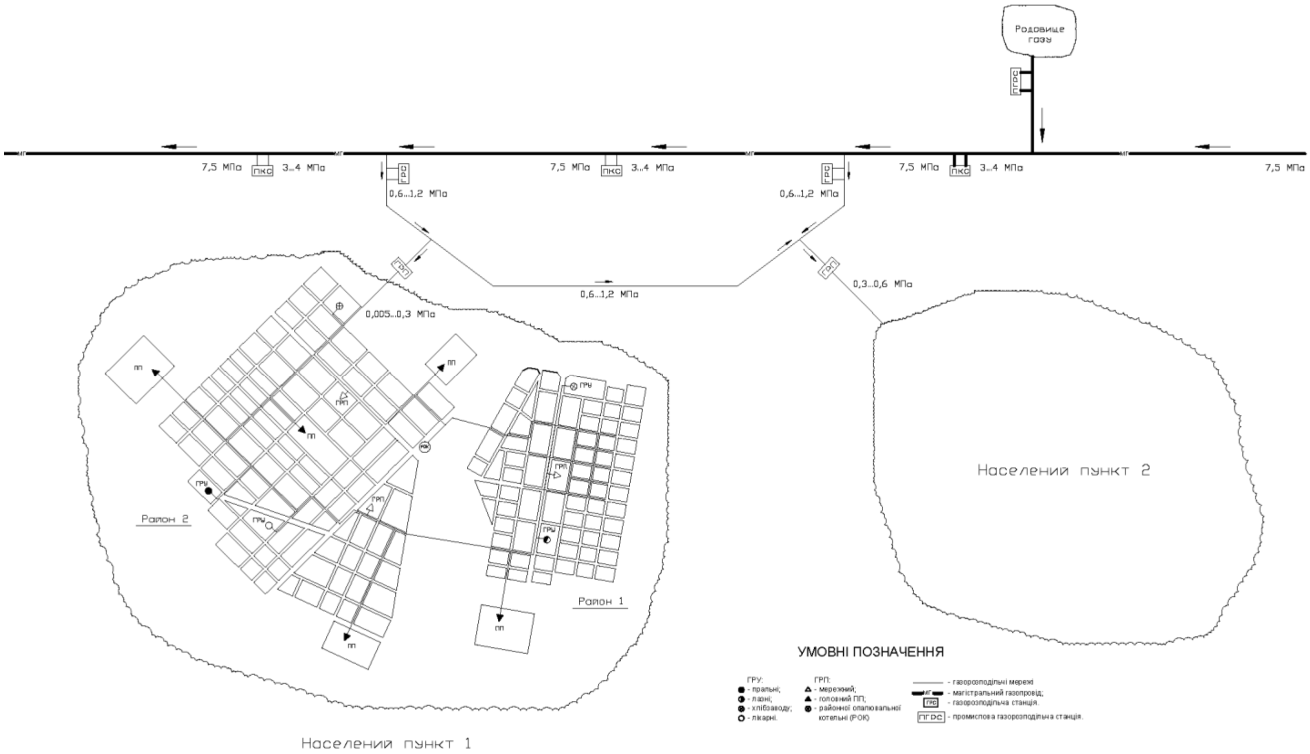


Fig. 7 – Example of settlement gas supply system

Export of biomethane by existing gas networks is one of the potential solutions for Ukraine. For connection to main pipelines requires large volumes of gas supplies under high pressure (not less than 3-4 MPa). This will require the construction of an additional compressor station and a corresponding increase in energy consumption. Ability to connect to main pipelines can be considered for large projects confirmed export contracts.

Practical implementation of the export capacity depends on the legislative framework and additional infrastructure. In practice, to connection to the distribution networks of medium and low pressure is more real. Produced in biogas upgrading systems pressure is mainly sufficient or even excess injection pressure in such networks. Minimum capacity of gas distribution network segment must exceed the capacity of biomethane producer.

Natural gas definition and quality standards

Gas distribution network in Ukraine was designed to transport natural gas only. The term "natural gas" means by Ukrainian low "natural gas and oil (passing) gas, methane of coal deposits and shale gas - a mixture of hydrocarbon and non-hydrocarbon components in a gaseous state at standard conditions (pressure - 760 mm Hg and a temperature of 20°C) and is a marketable product[30]. Depending on where the gas is going to be used to its quality requirements imposed in accordance with the technical conditions (TU) 320.00158764.007-95 (Table 7).

[30] Low of Ukraine «On Principles of Natural Gas Market functioning»

Table 7. Technical requirements for natural gas fuel[31]

№	Item	Value
1	Dew point by water at 4,0 MPa	not higher than -5°C
2	Dew point by hydrocarbons	not higher than 0°C
3	Hydrogen sulfide content	not more than 0,02 g/m^3
4	Mercaptan sulfur content	not more than 0,036 g/m^3
5	Oxygen volumetric fraction	not more than 0,5%
6	Low calorific value under standard conditions	not less than 32,5 MJ/m^3
7	Mechanical impurities	not more than 0,003 g/m^3

Gas quality in distribution networks must meet the requirements of state standard GOST 5542-87[32],[33] (table 8).

Table 8. Requirements for natural gas under GOST 5542-87

№	Item	Value	Control method	Comments
1	Low calorific value under standard conditions	not less tan 31,8 MJ/m^3 (7600 kcal/m^3)	GOST 27193-86 GOST 22667-82 GOST 10062-75	
2	Wobbe index range (high)	41,2-54.5 (9850-13000) kcal/m^3	GOST 22667-82	only to gas for household and communal use
3	Wobbe index deviations from nominal	not more than ±5%		
4	Mass concentration of hydrogen sulfide	Not more than 0,02 g/m^3	GOST 22387.2-83	By agreement with the consumer gas with a higher content of hydrogen sulfide and mercaptan sulfur accepted for some pipelines
5	Mass concentration of mercaptan sulfur	Not more than 0,036 g/m^3	GOST 22387.2-83	
6	The volume fraction of oxygen	Not more than 1,0%	GOST 22387.3-77 GOST 23781-83	
7	Weight of solids particles	Not more than 0,001 g/m^3	GOST 22387.4-77	
8	The intensity of the odor at 1% volume fraction of air	Not less than 3 points	GOST 22387.5-77	only to gas for household and communal use

Obviously, the degree of biogas upgrading and purification by present commercial technologies (CH_4 content in BM at 95-98%) is sufficient to meet the requirements of the above standards, so there is no technological barrier. However, biomethane does not fall under the term "natural gas", because without appropriate amendments in legislation implementation of the projects with injection of BM into the gas distribution network is not possible. Changes, for

[31] ТУ У 320.001.58764.007-95. «Combustible natural gases, served in the main gas pipelines. Technical specifications»;
[32] «Rules for gas monitoring during transportation gas in distribution networks, supply and consumption" approved by the Ministry of Fuel and Energy of Ukraine of 27.12.2005 № 618.
[33] GOST 5542-87 "Combustible natural gases for industry, communal and household use. Technical specification".

example, may relate to the definition of "natural gas". It should include also biomethane produced by both biochemical and thermochemical conversion of biomass under condition of compliance with the requirements of its existing standard.

Connection to the natural gas grid

Connecting of the customer objects to the gas distribution networks carried out by gas distribution company (GDC) on the basis of an agreement to join the gas network, the standard form of which is determined by NERC.

At the request of the customer GDC is obliged in 5-day period provide information on the transmission capacity of gas pipelines. After technical conditions specified and paid the customer receives a legal term for the signing of an agreement to join the project to the gas network. After signing an agreement the parties develop project documentation.

The next step is construction, installation and commissioning connecting the gas supply system of the customer to the gas network. Connecting the gas supply system of the customer should be subject to the requirements of the rules of customer security of gas supply systems in Ukraine[34]. Procedure for commercial gas metering governed by the rules of NG use for entities should be approved by NERC.

To date, the legislation does not envisage the possibility of joining producers supplying biomethane to the gas transportation system. It governs only the accession of natural gas and coal bed methane. Therefore, in practice, the grid operator can refuse to connect. In the new draft law "On the Principles of Natural Gas Market Functioning" this problem is currently scheduled to be resolved.

Biomethane use for vehicles

Ukraine is a country with traditional use of compressed natural gas as a motor fuel. According to the International Gas Union[35] (IGU) and the UN Economic Commission in Ukraine in 2011, there were 200,000 vehicles on compressed NG and about 300 NG filling stations for NG (Table 9). Ukraine is a world leader in the use of natural gas for trucks and buses.

Table 9. Use of natural gas as a motor fuel in the world

Country	Number of vehicles, thousands					World percentage %	Gas filling stations number	NG consumption mln m^3
	Total	Cars	Buses	Trucks	Other			
Pakistan	2850	2670	0,5		180	19,6	3330	
Iran	2859	2853	6,0			19,6	1800	467,0
Argentina	2031	2031				14,0	1898	235,4
Brasilia	169	1694				11,6	1790	163,9
India	1100	1069	23	0,7	6,9	7,6	683	163,2
Italia	761	759	2,3	1,2		5,2	858	62,0
China	600	370	150	30	50	4,1	2500	

34 «Правила безпеки систем газопостачання України» затверджені наказом Державного комітету України по нагляду за охороною праці від 01 жовтня 1997 року № 254.
35 Natural Gas for Vehicles – International Gas Union and United Nations Economic Commission for Europe Joint Report. – June 2012

Country	Number of vehicles, thousands					World percentage %	Gas filling stations number	NG consumption mln m^3
	Total	Cars	Buses	Trucks	Other			
Columbia	349	325	13,8	9,7		2,4	651	45,0
Uzbekistan	310	310				2,1	175	
Thailand	268	219	14,2	32	1,8	1,8	444	
Armenia	240	192	17,3	35		1,7	345	26,5
Ukraine	**200**	**10**	**120**	**70**		**1,4**	**294**	**83,0**
World	14550	13581	434	250	284	100,0	20681	1525,2

NG share in the consumption of motor fuels in Ukraine is relatively low. According to the energy balance of Ukraine[36] for 2012 road transport of Ukraine consumed 8438 toe (353.6 PJ) of motor fuel, of which 8394 toe of oil products and 44 toe (50 mill m^3) of NG. It means that share of natural gas in the consumption of motor fuels was 0.52%.

According to the National inventory of anthropogenic emissions of GHG in Ukraine during the 1990-2012[37] the use of NG a fuel for mobile combustion was much larger and amounted to 383 mill m^3 or 13.0 PJ, or 3.2% of the consumption of motor fuels (Table 10).

Table 10. Use of fuels by IPCC categories in physical and energy units (mobile combustion) in 2012

	tonnes (th m^3 for NG)	TJ	%
Natural Gas, th m^3	383 078,5	13034.6	3,2%
Petrol, t	4 442 682,9	199028.6	49,4%
Gasoil (Diesel fuel), t	4 036 256,2	170289.7	42,3%
Lubricating oils, t	1 639,7	65.9	0,0%
Liquefied propane and butane, t	430 317,7	20358,3	5,1%
TOTAL	9 179 051,5	402777.1	100,0%

BM market for the use as a motor fuel is almost unlimited. Since the properties of BM similar to those of NG, the use of BM as a motor fuel is possible in any proportions with NG. Thus there is no need to modify the vehicle or the gas distribution network. An additional advantage is that the BM is a renewable substitute for NG, its utilization leads to a reduction of GHG emissions.

The number of vehicles using compressed natural gas and biomethane, growing in the world rapidly. There were about 14.5 million vehicles using NG in the world in 2011 with an average annual increase of 20-25%. The largest number of NG vehicles was in countries such as Pakistan, Iran, Argentina, Brazil, India. More than 700 million NG vehicles were used in Italy. In all mentioned countries NG is used mainly for passenger cars. A special feature of Ukraine is that NG is used for trucks and buses.

[36] Державна служба статистики України. http://www.ukrstat.gov.ua/

[37] Национальный кадастр антропогенных выбросов из источников и абсорбции поглотителями ПГ в Украине за 1990-2012 гг. – Государственное агентство экологических инвестиций Украины. – Киев. – 2014.

ECONOMICAL ASPECTS OF BIOMETHANE PRODUCTION

To assess the biomethane cost (BM from the network, compressed BM in gas filling stations) all production stages from preparation of raw materials till selling to BM consumer should be taken into account. Among the main components of the cost of the BM are the following:

- The cost of raw materials entering the BMS;
- The cost of biogas production in BMS;
- The cost of biogas purification, upgrading and compression;
- The cost of BM delivery to the consumer;
- The cost of BM filling (when used as MF).

Cost of raw materials can vary in a wide range of practically "zero" (waste at waste treatment facilities that do not have market value) to 0,02-0,05 €/kWh (190-475 €/1000m^3CH_4), based on maize silage corn at its value 20-30 €/t. The cost of raw materials is also affected by radius of delivery to the BMS.

The net cost of biogas production taking into account the operational and capital costs in BMS is from 0,023 to 0,042 €/kWh (220-400 €/1000m^3CH_4)[38]. This value depends on the efficiency of the technology, the overall capacity of biogas plant, the ratio of debt to equity in the investment cost.

The cost of biogas purification, upgrading and its compression before NG grid supply is by different sources from 0,022 to 0,035 €/kWh (210-330 €/1000m^3CH_4)[39]. The cost of treatment is influenced by a number of factors, namely:

- The composition of initial biogas, the need for preliminary purification of biogas.
- Requirements to biomethane.
- The technology for CO_2 removal (energy consumption, chemical materials, degree of recycling/methane leaks).
- Capacity of the treatment plant.
- Requirements for flue gas cleaning.

Specific cost of biomethane dependents more on its overall capasity, less on the type of used technology. In general, specific cost ranges from 1500 to 5500 €/Nm^3/h (see Fig. 8). It can be seen that with increasing of productivity station the difference of specific investment for different treatment technologies becomes smaller. The cost of small treatment plants with capacity up to 100 m^3/h of biogas exceeds 6000 €/Nm^3/h. There is a steady decline in the cost of biogas upgrading in time from the moment they enter the market and to date due to improvement of technology.

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[38] НТЦ «Биомасса», 2014

[39] *Johan Vestman, Stefan Liljemark, Mattias Svensson*. Cost benchmarking of the production and distribution of biomethane/CNG in Sweden / SGC Rapport 2014:296

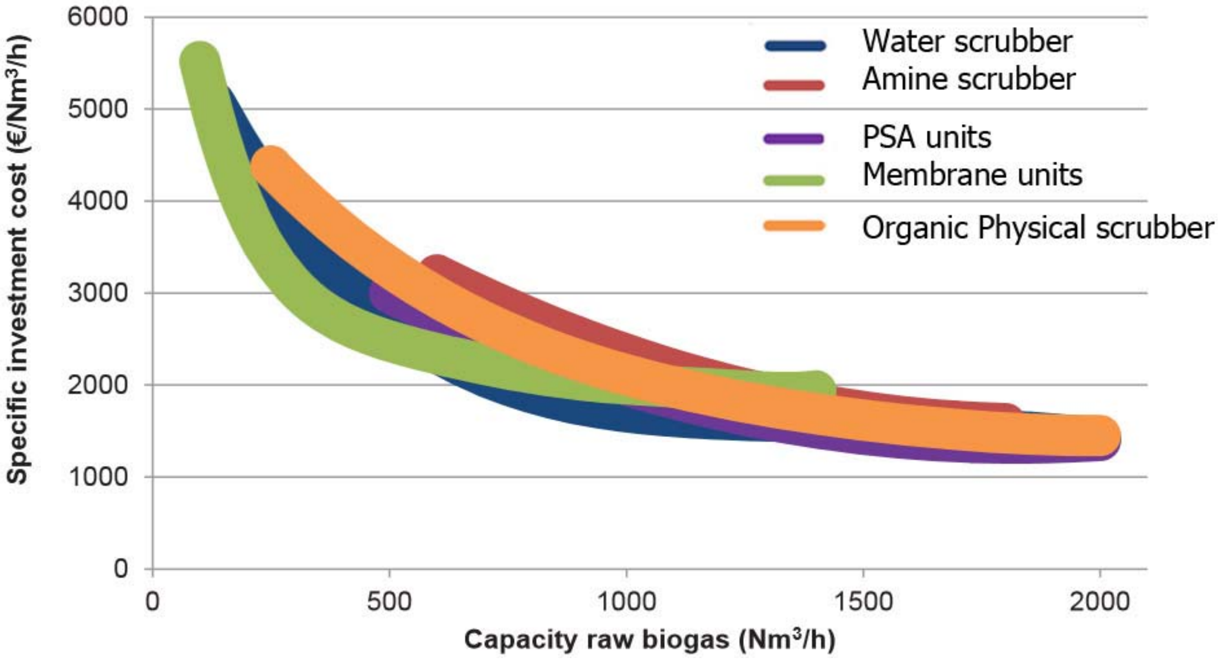

Fig. 8 - Specific investment costs for biogas upgrading plants using different technologies[40]

In general, the cost of delivery to the consumer will depend on the distance and delivery method (NG grid, vehicle) and BM status (liquefied, compressed). Final cost injected BM into the gas grid depends on the technical conditions for connecting to the grid, namely:

- Required pressure for BM;
- Required calorific value (the need of propane adding);
- The need to monitor the quality of BM;
- The need of odorisation;
- Distance from BM producer to connection point.

Contribution of a gas filling station in the final cost of BM on the example of Sweden is 0.0044 €/kWh (41.6 €/1000m^{3}BM). The average cost of delivery BM in Sweden is 0.0088 €/kWh (83.6 €/1000m^3CH_4). Table 11 provides data of the Swedish Gas Centre (SGC) on the specific cost of individual stages of BM production and sale as motor fuel. The average BM production cost of BM for cars in Sweden in 2012 was 0.1485€/kWh (1410 €/1000m^{3}BM)).

Table 11. Average cost of BM production stages as motor fuel in Sweden, €/kWh[41]

	Biogas	Upgrading	Delivery		Filling	Total
			NG grid	Vehicle		
SGC	0,059…0,095	0,034…0,035	0,007…0,009	0,013…0,017	0,004…0,008	0,107…0,149
Other data	0,011…0,062	0,022…0,033	0,010…0,017		0,012…0,017*	0,155**

*retail price;

** average cost of compressed NG in Sweden in 2012

[40] *Fredric Bauer, Christian Hulteberg, Tobias Persson, Daniel Tamm*. Biogas upgrading – Review of commercial Technologies / SGC Rapport 2013:270

[41] SGC Rapport 2014: 296

The SGC report notes that the BM cost significantly affects by low level of BMS capacity utilization. To improve the profitability of BM production is recommended to consider the potential income from the sale of fermented mass as organic fertilizer.

In Germany, the average cost of BM is 0,083 €/kWh (788 €/1000m^{3}BM) for BMS with 500 Nm^3/h of biogas capacity. With the increase of capacity up to 2000 m^3/h the cost goes down to 0,068 €/kWh (645 €/1000m^{3}BM). In this case, the main component of the cost refers to the cost of biogas production from crops materials, it is 0.0575 and 0.0525 €/kWh for the respective power stations. The cost of biogas upgrading is 0.023 and 0.014 €/kWh respectively. The cost of connection to the NG grid is 0,002-0,001 €/kWh. Similar cost has monitoring of BM supply to NG grid.

Logistics of BM production and supply may be different. The simplest case is the production of biogas and its upgrading on an individual biogas station. Upgrading as well as filling in case of the use of biomethane as a motor fuel can be combined for several biogas plants. In this case, specific cost of upgrading filling is reduced, but there is a need to build additional pipelines, leveling the economic benefits of such a union. Several variants of the cost and supply of biomethane are shown in Table 12.

Table 12. Example of the cost of BM production and delivery as motor fuel (capacity of 1 mill m^3 BM/year or 500 kW) [42], mill €

	One biogas plant	Three biogas plants with 5 km pipeline to each plant	Six biogas plants with 10 km pipeline to each plant
Biogas plant	2,0	2,0	2,0
Piping	0,2	1,0	2,0
Upgrading	0,7	0,5	0,4
Gas filling station	0,5	0,4	0,3
Total	3,4	3,9	4,7

BIOMETHANE PRODUCTION COST ASSESSMENT FOR UKRAINE

Possible options of biomethane production and energy use based on manure feedstock and maize silage are evaluated below. Considered options of BM energy use include:

- The replacement of natural gas by BM for biomethane industrial plants;
- The implementation of biomethane as a vehicle fuel at gas filling stations;
- Production of electricity and heat by CHP belonging to industrial enterprises;
- Production by CHP of electricity for distribution company by "green" tariff 12,39 €cent/kWh (k=2.3) or 16,16 €cent/kWh (k=3.0) and thermal energy for industrial enterprises.

Two scenarios evaluated with sets of input parameters, which form the lowest possible and the highest possible production cost of biomethane. Current tariffs for electricity, thermal energy for

[42] Natural Gas for Vehicles – International Gas Union and United Nations Economic Commission for Europe Joint Report. – June 2012

industrial enterprises, the cost of compressed NG as well as actual "green" tariff were used. Accepted parameters are given in Table. 13.

Table 13. Price of energy and energy carriers used the calculation

Price of NG as motor fuel	UAH/liter	7,15
Price of NG for industry consumers	UAH/1000 m^3	6300
Price of electricity for industry consumers	UAH/kWh	1,36068
Price of thermal energy for industry consumers	UAH/Gcal	1000

The profitability of BM by type of project in case of sale of digested material as organic fertilizer is also evaluated. The cost of organic fertilizers is calculated based on the content of nitrogen, phosphorus and potassium (NPK) and the market value of NPK fertilizer. The results are shown in Table. 14.

Table 14: Cost and profitability of BM production in Ukraine

Type of row material		Manure/Litter		Maize silage	
The combination of the input parameters		min	max	min	max
Cost of raw materials	€/т	0.0	0.0	12.8	25.6
Production cost of energy from BM					
In NG grid input	€cent/kWh	1.9	6.4	2.4	8.2
	€/1000 nm^3	178	599	226	770
In NG grid output	€cent/kWh	2.6	8.1	3.1	9.9
	€/1000 nm^3	243	758	291	930
Motor fuel	€cent/kWh	3.0	8.9	3.5	10.7
	UAH/l	2.7	8.0	3.2	9.6
CHP (electricity plus heat)	€cent/kWh	3.6	10.4	4.1	12.2
Profitability					
NG for industry	%	63.5	-47.5	36.7	-57.2
Motor fuel	%	165.1	-10.6	126.6	-25.9
CHP (electricity plus heat for industry)	%	92.6	-34.1	68.5	-43.9
CHP (electricity GT k=2,3 plus heat for industry)	%	165.4	-9.1	132.2	-22.7
CHP (electricity GT k=3,0 plus heat for industry)	%	218.9	9.2	179.0	-7.1
Profitability with fertilizer sale					
NG for industry	%	354.0	-29.3	48.2	-28.0
Motor fuel	%	416.9	5.9	136.8	1.1
CHP (electricity plus heat for industry)	%	304.4	-19.9	77.3	-20.3
CHP (electricity GT k=2,3 plus heat for industry)	%	377.2	5.0	141.0	0.9
CHP (electricity GT k=3,0 plus heat for industry)	%	430.7	23.4	187.8	16.5

It can be seen that initial set of parameters affects significantly the economic feasibility of BM production. Based on the above results the following preliminary conclusions can be made:

- Production cost of BM can vary from 178 to 930€/1000m^3.
- Production cost of electricity from BM ranges from 0,019 to 0,122 €/kWh.
- Production cost of motor fuel from BM ranges from 2.7 to 9.6 UAH / liter.

- The most cost-effective projects will be production of electricity and thermal energy in case of electricity sale by green tariff and the most complete sale of heat at the rate for industrial enterprises; the use of maize silage is most cost effective way to produce BM.
- Production of compressed BM and its sale as motor fuel can be cost-effective under certain conditions; again the use of maize silage is most cost effective way of BM production.
- Production of BM followed by substitution of NG in industrial enterprises at current price of NG are less attractive and could be profitable only at low cost of raw materials or technology, etc., taking into account the sale of organic fertilizers;
- For all types of projects, the possibility of organic fertilizers sale significantly increases the profitability of projects.

Thus, today the BM consumption in the domestic market could be limited due to high cost of its production in comparison with the prices of NG. Biomethane production prospects are largely dependent on legislative support in the Ukrainian market, as well as the possibility of its exports.

Cross-border trade is possible in case of dissemination of incentives used in the domestic market of the importing country for imported BM. There are two basic possibilities of BM export. The first one consists in the physical transport of BM via pipelines. Connecting to main pipelines may be appropriate for large producers of BM. The second option can be implemented on the basis of agreements between two or more countries, which allow the share of BM certificates of origin. In this case physically BM can be fed into the low pressure distribution network and consumed in the local market, replacing the appropriate amount of NG main pipelines. To implement this mechanism, it is necessary to develop national registries of BM production and consumption in all participating countries.

Examples of feasibility studies of BM production based on chicken litter with maize silage

One type of the potentially promising projects can be the production of biomethane on the basis of large poultry farms in Ukraine, the number of which has increased substantially in recent years. For many of them, the problem of stabilization and safe disposal of waste is very important. At the same time, a large amount of litter with adding technologically reasonable amount of green biomass (for example maize silage), can be a good precondition for the implementation of BM projects.

Examples of feasibility study for construction of BM production facilities on the basis of poultry farms with livestock from 0.58 to 4.66 million heads with the addition of 25% maize silage (in organic matter) are described below. Water scrubber was chosen as a method of biogas upgrading. Biomethane is injected into the gas distribution network and then is used for the production of electricity and heat.

Following general conditions are used for the assessment of the main technical and economic indicators of the projects (see Table 15):

- electricity tariff in two different versions with a green tariff 2,3 (12,39 €cents/kWh excluding VAT) and 3,0 (16,16 €cents/kWh excluding VAT);
- the purchase price of maize silage is 200 UAH/t;

- The cost of poultry manure is zero;
- Borrowed financing of the project is 50% (10-year loan at 10% per annum);
- 50% of the fermented mass is sold at market-based price (223 USD/t) as fertilizer;
- 50% of the annual output of thermal energy sold at the rate of 1000 UAH/Gcal.

Table 15: Technical and economic performance of BMS in the poultry litter

Item	Units	Value			
Number of poultry	th. heads	580	1 160	2 330	4 660
Maize silage	t/year	6 880	13 761	27 640	55 279
Land area for maize	hectares	229	459	921	1 843
Biogas upgrading capacity	nm^3/h (BG)	250	500	1 000	2 000
BM production	nm^3/h (97% CH_4)	147	293	586	1 172
Investment	mill €	4,17	6,13	9,10	13,61
Including biogas upgrading	*mill €*	*1,38*	*1,74*	*2,20*	*2,78*
Operation cost	mill €/year	0,30	0,52	0,96	1,84
Payback period					
K_{3T} = 3,0	years	6,8	4,0	2,7	1,9
K_{3T} = 2,3	years	10,2	5,5	3,5	2,4
Electricity cost	€cent/kWh	13,3	10,8	9,2	8,1

As can be seen, the scale of the project significantly affects the economic performance. So, under the same initial conditions simple payback period with electricity green tariff 16,16 €cents/kWh drops from 6.8 years for farm with livestock 580 thousand heads to 1.9 years with livestock 4660 thousand heads. For 12,39 €cents/kWh t it drops from 10.2 years to 2.4 years respectively. This type of projects, in case of electricity sale at the rate of 16,16 € cents/kWh and complete heat sale at the rate of 1000 UAH/Gcal can be economically attractive for poultry farms with livestock from 1 million heads even without sale of organic fertilizers.

UABIO'S PROPOSALS FOR BIOMETHANE

Preconditions of biomethane production in Ukraine

Ukraine has a number of preconditions for the development of biomethane projects, namely:

1. Large consumption of NG, critical dependence on foreign markets, including natural gas imports from Russia.
2. High and volatile prices for imported NG, upward trend for all categories of consumers.
3. Developed transport infrastructure of NG including both pipelines connecting Ukraine with European countries, and a network of distribution pipelines that provide most of the population of Ukraine with NG.

4. Large BM production capacity from agriculture waste, significant potential of land resources, including unused land suitable for the cultivation of energy crops for the production of biomethane, potentially lower cost of energy crops compared with Western European countries.
5. The presence of a large number of agricultural holdings with the potential for the development of large-scale projects for biomethane production.
6. Tradition of NG using as a motor fuel, developed network of gas filling stations.

Barriers for biomethane production development

The idea of producing biomethane from biological raw material is relatively new in Ukraine. There are economical and legal barriers to the development of BM technologies in Ukraine, namely:

1. The relatively high cost of BM production compared to the prices for imported natural gas.
2. Subsidizing of domestic prices of natural gas for the population and housing.
3. The absence of any subsidies, incentives, supports schemes for BM producers and consumers.
4. The lack of attention for BM in the Ukrainian legislation regarding gas supply.
5. The lack of a standard for the production of BM.
6. The lack of technical conditions for connection to the gas network.
7. The absence of effective state program for the development of BM production and consumption.

UABio's proposals

In order to initiate the production of BM in Ukraine the following activities should be implemented:

1. Adopt amendments to the Law of Ukraine "On Electric Power Industry": Starting with 01.01.2015 increase green tariff factor for power facilities running on biomethane up to k=3,0 (16,16 €cents/kWh, excluding VAT) under condition at least 50% of the thermal energy utilization.
2. Make changes to the Law of Ukraine "On Principles of Natural Gas Market functioning." In particular, changes to the definition of "natural gas" to: "natural gas and oil (passing) gas, natural gas (methane) of coal deposits, shale gas, methane of biological origin - a mixture of hydrocarbon and non-hydrocarbon components residing in the gaseous state under standard conditions (pressure - 760 mm Hg and a temperature of - 20°C) and is a marketable product".
3. Develop standards and specifications for the production of BM and its use in gas networks, which ensure non-discrimination when connecting BM producers BM to distribution and, potentially, the main gas pipelines.
4. Finalize and approve the draft "National Action Plan for Renewable Energy" in terms of increasing the volume of the use of biofuels, including biogas and biomethane for the

production of heat and electricity. Determined on the state level specific goals for the production of biomethane and its timetables.

5. Provide and ensure the development of a national registry of BM production and consumption to confirm the source of BM origin, as well as compliance with similar registers in the EU. To interact with the national registry similar registries of European countries.
6. Provide stimulating the development of ecological transport in urban areas, including working on the BM. According to the experience of Sweden for this purpose programs facilitating long-term investment in municipal projects that would reduce GHG emissions, as well as contributing to the production, distribution and use of biogas/biomethane.

CONCLUSIONS

The level of natural gas consumption in Ukraine is high. Share of NG in the final energy consumption is more than 40%. At the same time Ukraine provides a natural gas from its own resources by about a third, the rest of NG is imported primarily from Russia. Reducing the NG consumption and its substitution with alternatives is a matter of national security. One possibility is the replacement of NG by production of biomethane.

Ukraine has significant potential for the production of biogas/biomethane. The total potential of BG/BM from agriculture waste, MSW, municipal and industrial waste water is estimated at 3.2 billions m^3 CH_4 per year. Another 3.3 billion m^3 CH_4 can be obtained by growing energy maize (or other energy crops) at 1 million ha (3% of the total arable land in Ukraine). Realization of this potential is determined by the strategy of land resources use. Significant additional potential production of BM associated with the development of gasification and methanation of woody biomass.

Ukraine is a country with a developed system of gas supply. The total length of gas distribution networks is 246 thousand kilometers. More than 70% of Ukraine's population has access to NG. Thus, at the biggest part of Ukraine is technically possible to connect BM producers to distribution networks of medium and low pressure for local BM consumption.

The presence of a unique gas pipelines system makes possible biomethane export from Ukraine to Western Europe. Some western countries stimulate production of BM. For the development of BM exports to the EU a national registry of production and consumption of BM is needed to confirm the source of its origin and meet certain conditions to comply with similar registries of the EU and to ensure interaction between similar registries of European countries.

Ukraine is a country with traditional use of compressed NG as a motor fuel. There were 200,000 vehicles on compressed NG and about 300 gas filling stations in 2011. The market of BM as motor fuel is almost unlimited. Since the properties of BM are similar to those of NG, the use of BM as a motor fuel is possible in all proportions with NG. Thus there is no need to modify the vehicle or the gas distribution network.

The production cost of BM is still relatively high, the competitiveness of BM depends on natural gas prices at the local or export markets. Minimal cost of BM is evaluates as about 180 €/1000 m^3. Production cost of energy from BM ranges from 0.02 to 0,12 €/ kWh; The production cost of the gas motor fuel is from 3 to 10 UAH/liter. The most potentially profitable projects will produce electricity and thermal energy by CHP in case of green tariff implementation and 100% heat purchase by industrial enterprises. Production of compressed BM and its sale a motor fuel may also, under certain conditions, be cost-effective. Production of BM followed by substitution of NG in industrial enterprises at the current prices are less attractive and can be profitable only at a low cost of raw materials, equipment, etc. For all types of projects, the possibility of selling of digestate as organic fertilizer at market-based prices increases significantly the profitability of projects.

Development of BM production needs government support. In Ukraine, there is no legislation to facilitate the production and utilization of biomethane. In order to stimulate of BM production in Ukraine, it is necessary to implement a set of related measures, among which are implementation green tariff with k=3.0 (16,16 €cents/kWh excluding VAT) for electricity with mandatory utilization of heat, the development of standards and specifications for the BM production, the guarantee of non-discrimination when pumping BM in distribution (low pressure) and, potentially, main (high pressure) gas network.

Specific goals for BM production and the timeline for their achievement have to be specified on the state level. National registry of production and consumption of biomethane should be developed.

Abbreviations

AD – Anaerobic Digestion;
BG – biogas;
BGP – Biogas plant;
Bio-SNG – Synthetic Natural Gas of Biological origin;
BM – Biomethane;
BMS – Biomethane Station;
CHP – Combined Heat and Power;
CNG – Compressed Natural Gas;
EBA – European Biogas Association;
EU – European Union;
GCS – Gas Compressor Station;
GDC – Gas Distribution Company;
GDS – Gas Distribution Stations;
GHG – Greenhouse Gas
GTS – Gas Treatment Station;
HHV – High Heating Value;
LBG – Liquefied Biogas/Biomethane;
LCC – Lignocellulosic complexes;
LFG – Landfill Gas;
LNG – Liquefied Natural Gas;
LPG – Liquefied Petroleum Gas;
MF – Motor Fuel;
MSW – Municipal Solid Waste;
NCSPURC – The National Commission of the State Public Utilities Regulation;
NERC – National Energy Regulation Commission;
NG – Natural Gas;
NGVA – Natural and bio Gas Vehicle Association;
PSA – Pressure Swing Adsorption;
RES – Renewable Energy Source;
TPP – Thermal Power Plant;
UGS – Underground Gas Storage;
UAH – Ukrainian Hrivna;
UGTS – Unified Gas Transportation System of Ukraine;
VGFCS – Vehicle Gas Filling Compressor Station.

Energy Units

J	–	Joule;
tce	–	tonne of coal equivalent;
toe	–	tonne of oil equivalent;
cal	–	calorie;
Wh	–	Watt per hour.

Energy Units Conversion Table

	GJ	tce	toe	Gcal	MWh
GJ	1	0,0341	0,0239	0,239	0,278
tce	29,31	1	0,700	7,0	8,130
toe	41,87	1,429	1	10,0	11,63
Gcal	4,19	0,143	0,100	1	1,163
MWh	3,60	0,123	0,0861	0,861	1

Previous publications of UABIO

1. http://www.uabio.org/ru/activity/uabio-analytics
1. *Position Paper N 1* "Position of bioenergy in the draft updated energy strategy of Ukraine till 2030".
2. *Position Paper N 2* "Analysis of the Law of Ukraine "On amending the Law of Ukraine «On Electricity" No5485-VI of 20.11.2012".
3. *Position Paper N 3* "Barriers to the development of bioenergy in Ukraine".
4. *Position Paper N 4* "Prospects of biogas production and use in Ukraine".
5. *Position Paper N 5* "Prospects for the electricity generation from biomass in Ukraine"
6. *Position Paper N 6* "Prospects for heat production from biomass in Ukraine"
7. *Position Paper N 7* "Prospects for the use of agricultural residues for energy production in Ukraine".
8. *Position Paper N 8* "Energy and environmental analysis of bioenergy technologies"
9. *Position Paper N* 9 «State of the art and prospects for bioenergy development in Ukraine».
10. *Position Paper N 10.* «Prospects of cultivation and use of energy plants 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. The Association was officially registered on 8 April 2013. Among UABio members there are over 10 leading companies and over 20 recognized experts working in the field of bioenergy.
http://uabio.org

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