Assessment of biogas situation in Belarus Republic

Ekaterina Kuzina MSc Environmental Management CAU, kuzina.katia@list.ru
Supervisor: Prof. Dr. Uwe Rammert, uwe.rammert@t-online.de

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Contents

Abstract

From March 26th to 30th a biogas mission was organized in the framework of the Baltic Compass Project. During the mission biogas plants were visited in Belarus Republic. The purposes of the mission were to offer consultations about planning of biogas plants, to analyze local current problems and immediately give recommendations if possible. During the mission it was found that Belarus has huge potential for the biogas production development. According to statistics, at average, the energy potential of Belarus just from agricultural sector may be 2.5 billion m^3 of gas per year. During the visits it was clarified that biogas plants are not designed for the local climate and available types of biomass. The equipment is rather designed for substrate with a high content of corn silage which automatically created a number of problems in the operations. So, this report identifies urgent problems of the biogas production, gives an assessment of planning and provides possible suggestions to improve the situation of the biogas industry development in Belarus.

Introduction

The project "Baltic Compass" encompasses in a practical manner the political ideas of the HELCOM Baltic Sea Action Plan and the EU Strategy for the Baltic Sea Region (more information: http://www.balticcompass.org/index.html). The major aim of the project is to foster win-win solutions for agriculture and environment, meaning to work for reduction of agricultural nutrient emissions to the Baltic Sea while in the same time business development. Biogas production on livestock manure has been selected as one of the win-win technologies, which Baltic Compass promotes via different activities and investments.

The mission was organized to Belarus Republic, where there were visited biogas plants at the agricultural sector (these plants use animal manure as biomass).

The purposes of the mission are to offer consultations about planning of biogas development, to analyze local current problems and immediately give recommendations if suitable. Work Package 4 of the Baltic Compass project plans to develop a pamphlet with some general guidelines for biogas feasibility studies.[1]

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[1] Based on: Henning Lyngsø Foged, WP4 leader, Terms of reference for mission to Belarus, 2011

The mission involved:

- Lars Baadstorp, biogas expert, Plan Action, Denmark
- Katia Kuzina, master student, Kiel University, Germany
- Henning Lyngsø Foged, WP4 leader, Agro Business Park, Denmark
- Nikolaj Kapustin, chief of laboratory of using fuel and energetic resources, Belarus

A development of biogas production has started a few years ago in Belarus. Biogas production is new in Belarus in comparison with Denmark, Austria or Germany. The main purposes to develop Biogas plants are

- to increase electricity and heat energy production using alternative resources decreasing a dependency out of natural gas
- to reduce emission of greenhouse gasses such as CO_2, CH_4, N_2O
- to raise the quality of fertilizers from animals due to digesting manure during the Biogas process

According to statistics, Belarus has a huge potential for biogas development and efficiency. There are about 100 cattle breeding complexes a total animal population about 3.5 mln heads; approximately 105 pig farms with pig a total population above 2.5 mln heads; around 45 poultry farms with a total chicken population 22 mln heads (Figure 1). At average, the energy potential of Belarus just from agricultural sector may produce 2.5 billion m^3 of gas per year, where 5 mln MW/h of electricity, 10 mln MW thermal energy and 70 mln t of digested high quality fertilizer.[2] According to the National Academy of Sciences of Belarus calculation, the electricity demand of agricultural sector comes to 3.5 million MW/h.

[2] Based on: A.Basaevsky Profit out of waste. Biogas technology in Belarus, 2011

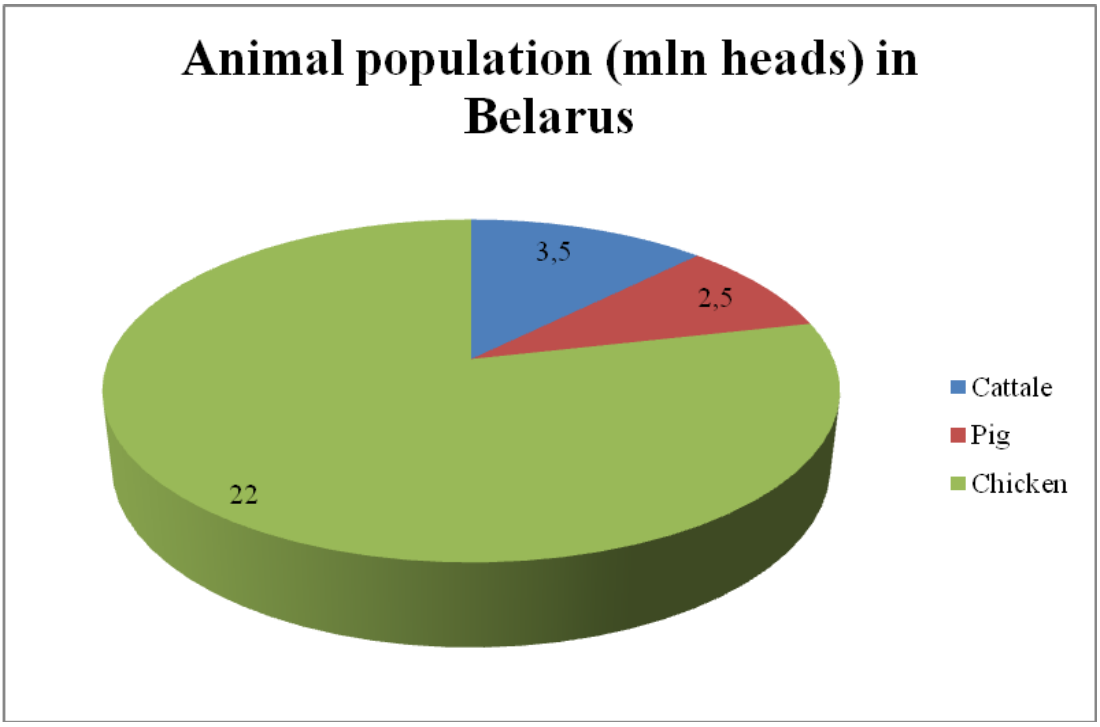

Figure 1: Animal population in Belarus (mln heads), 2011

Materials and methods

During the mission the following companies were visited:

- Municipal Agricultural unitary Enterprise "Pedigree State Farm-Combine "Zapadny" (400 km from Minsk, 25 km from Brest)
- Poultry farm "Belorusky" (20 km from Minsk)
- Planned biogas plant "Zazerye" at farm belonging to RUE "SPC NAS Belarus for agricultural mechanization"
- Agricultural complex "Snov" (150 km from Minsk).

During the mission all data from plants were written in a special table. The example of this table can be found in Annex A.

In the frame of the work interviews with representatives of the visited companies were performed:

March 26th there was a discussion between the expert group and the general director of Ramtex firm and the deputy director of Microbeltech firm. These Belarusian private companies produce and implement cogeneration engines on the Belarusian market. They are interested in biogas production development in Republic.

March 27th there was a meeting with the general director and the chief engineer of the Municipal Agricultural unitary Enterprise “Pedigree State Farm-Combine “Zapadny”. The area of agricultural land is 11.4 thousand ha, whereof 7.1 thousand ha is arable land. The farm has 67.2 thousand heads of pigs on stable and produces about 190 thousand heads fatteners per year. All gathered information about biogas plant “Zapadny” can be found on Annex B. On Picture 1 it is shown two digesters and one cogeneration system of biogas plant “Zapadny”.

Picture 1: Biogas Plant “Zapadny” the 27.03.2012 (source: Kapustin)

March 28th the poultry farm “Belorusky” was visited where we had a conversation with the executive director about biogas plant “Belorusky” (Picture 2). The discussion was about problems of low biogas productivity, problems with equipment, and high H_2S content. All gathered data about biogas plant “Belorusky” can be found in Annex C.

Picture 2: Biogas Plant “Belorusky”: primary and secondary digesters the 28.03.2012 (source: Kuzina)

March 28th we also had a meeting with Vladimir Samosyk the general director of the National Academy of sciences of Belarus. The Academy is one of the partners of Baltic Compass. During the meeting important questions about opportunities to prevent nitrogen emission from open lagoons to the atmosphere in the farms were discussed.

March 28th the expert group has visited “Zazerye” Plant (see Picture 3). This plant belongs to the Scientific-practical center of the National academy of sciences of Belarus for agricultural mechanization. It is still under construction. On this farm Nikolaj Kapustin was discussed with. He is a chief of laboratory of using fuel and energetic resources, one of the member of the Baltic Compass, and he is supervises the design of the Plant. All gathered information about information “Zazerye” Plant can be found on Annex D.

Picture 3: Primary and secondary digesters of biogas Plant “Zazerye” the 28.03.2012 (source: Kuzina)

March 29 th there was a meeting with the chief engineer and the chief technologist of the Agricultural complex “Snov” (Picture 4). This biogas plant has 100 % of investment capital from EU concern. All gathered information about biogas plant “Snov” can be found on Annex E.

During the mission literature in Russian language about planning, design and development of biogas plants in Belarus Republic was analyzed. Names of articles can be found in the literature chapter.

Based on theoretical and practical data an evaluation of the biogas production on the following parameters was performed:

- Planning of biogas plant
- Design of plant
- Ecology and environment
- Economy and Financing

The results can be found in to the next chapter.

Picture 4: Meeting of experts with representatives of the Agricultural complex "Snov" the 29.03.2012 (source: Kuzina)

Results and Discussion

The gathered information shows that all visited biogas plants were built between 2007 and 2011. The investment capital (full or part) was received from National Ministries of Belarus Republic and European companies. Most of contractors were from Germany or Austria.

The preliminary investigation shows that the design of Biogas Plants has the same or very similar construction type (see Figure 2). So it means that the technical conditions are the same.

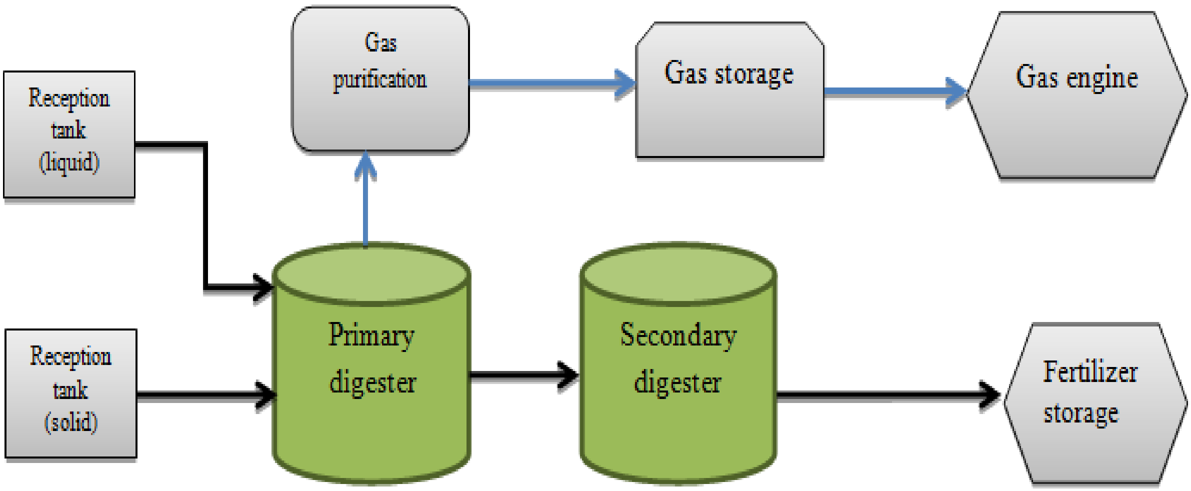

Figure 2: The schematic diagram of Biogas Plants in Belarus

The animal manure (solid and liquid) from the farm enters the system in the reception tank. Sometimes a reception tank for liquids is absent and manure goes directly from the farm into the primary digester via a slurry tanker (Picture 5). The size of the reception tank is about 300 m^3; the digester (primary and secondary) size is about 1500 m^3 of each. For the gas purification a biological process is used. All collected biogas is used for the electricity production. The digested fertilizer from the storage moves to open lagoons, then to the fields.

For biomass cattle manure, pig manure or chicken manure is used with additional amount of waste such as straw or slaughterhouse waste. In Belarus all digesters have the mesophilic regime, with temperatures about 34-38°C. The level of pH varies from 6.5 to 8.1 depending on ammonium content. The power of Biogas Plant is about 8-10 MW/day.

Picture 5: Pumping of liquid biomass into the digester from a slurry tanker on the biogas plant at the "Snov" farm (source: Kapustin)

During the mission it was identified that the visited biogas plants were not adapted to this climate and type of biomass, neither the size of the farms (the amount of livestock manure they produce). The equipment is designed for a large proportion of corn silage digestion what automatically created a number of problems in the operations of all visited biogas plants.

Subject: ***Pump system***

Problem: The pump transporting the biomass from the reception tank to the primary digester does not perform its function well, because it is designed for corn instead of manure biomass. Specifically, if solid biomass is pumped into the digester, it is always clogged by straw materials and sticking manure. Thus, it is necessary to clean.

Solution: There are many possibilities to solve this, but according to the costs and people mentality is just a few. First variant is to insert a grinding machine cutting the solid biomass into small particles. It must be located before the pump improving passage through it. Moreover the milled biomass is better processed by bacteria. Another solution is to buy a new pump especially for the manure biomass with bigger diameter. But experience shows that Belarusian farms cannot finance a new pump system or grind machine. Most of the time people simply have to stop the automated process of filing, and to replace it for manual work.

Subject: **Primary digester**

Problem: The design of the primary digester creates next problem. The used kind of digesters (Figure 3A) are meant for digestion of primarily corn silage, have typical sizes for farm scale plants in countries with averagely higher temperatures like Germany and Austria. So, the volume of tank is not enough for digestion of manure on the large livestock farms in Belarus, and they are insufficiently insulated for the Belarus climate.

Solution: It is recommended to use digesters meant for digestion of manure biomass. The diameter (D) of digester must be less then high (h) in order to make the most energy efficient mixing of the tanks (see Figure 3B).

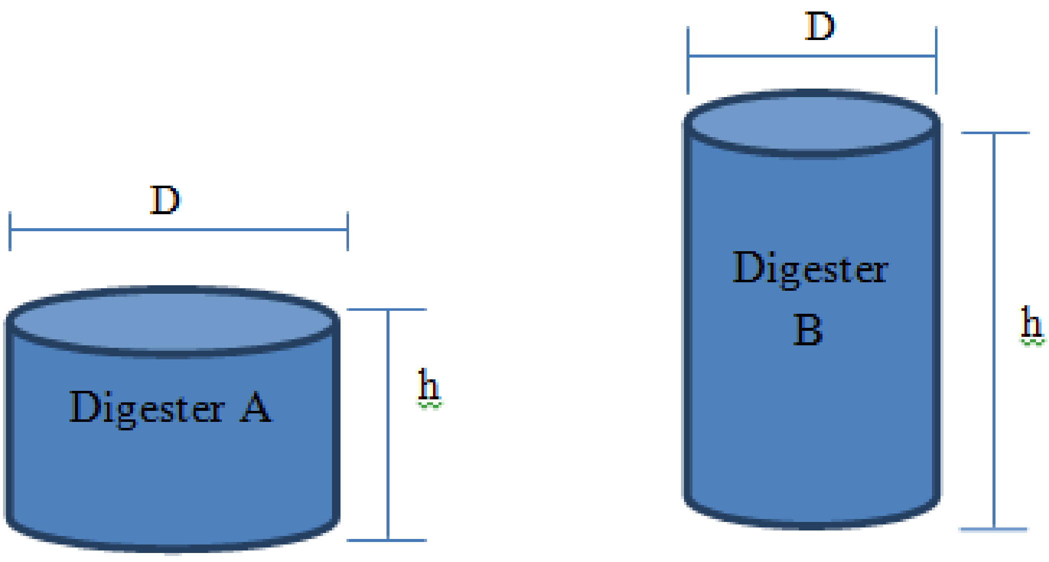

Figure 3: Types of vertical digesters. Digester A- built in Belarus, it is good for corn manure, when D=h. Digester B is recommended to build in Belarus for manure biomass, when D id smaller than h.

Subject: **Overflow between digesters**

Problem: Sedimentation. An overflow moving biomass from primary digester to secondary digester is the reason of sedimentation problems (see Picture 5). The corn biomass does not contain sand, and an overflow is a good and cheap solution for the process. However, the manure biomass' content of sand is depositing in the primary digester. So, all plants have to stop the process and clean the reactor from sand each year.

Picture 5: Biogas Plant "Belorusky". Between two digesters the yellow pipe grants for the overflow of biomass (source: Kuzina)

Problem: Heating system. The problem of sedimentation is also related to the heating system. The large amount of sand accumulates in the primary digester (1-2 m) and does not transmit heat from the heating system locating on the bottom of digester, leading to only small temperature difference in the in-going and out-going heating water. This situation leads to a decrease in temperature of the process.

Solution: A solution is to put one pump between primary and secondary digester (Figure 4). Therefore all sediment from the bottom will move by pressure into the secondary digester. It is a standard procedure to clean the secondary digester without the necessity to stop the whole process.

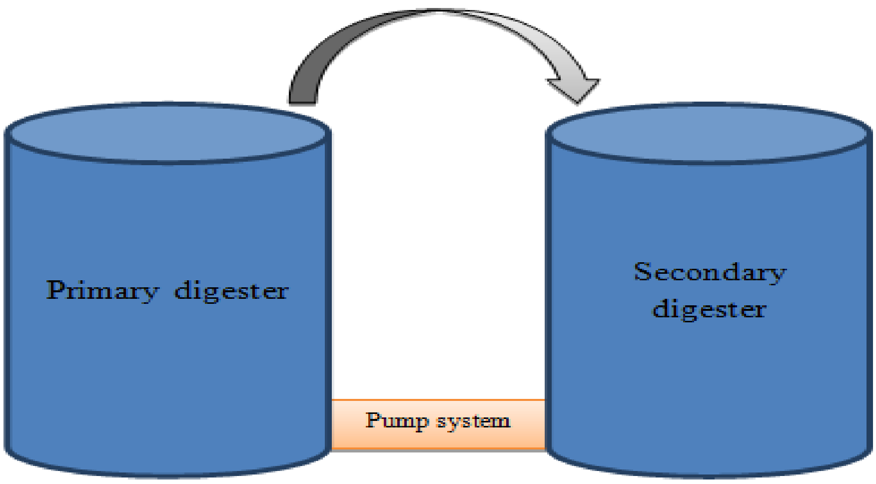

Figure 4: The possibilities to move biomass from primary to secondary digesters, where the arrow shows overflow method, and the pipe shows pumping method.

Subject: **Weather**

Problem: The temperature during the winter is below -20° C. Because of low temperature and high moisture content the biomass storing outside constantly freezes. Also some equipment is not designed for this climate.

Solution: To insulate the equipment locally. To make a plant design based on the local climate.

Subject: **Temperature regime and insulation thickness of digesters**

Problem: All biogas plants in Belarus have the same problem with temperature regime and insulation thickness of digesters. The digestion happen at mesophilic regime (t=34-40° C) with an isolation of the digestion tank of only 8-10 cm. According to the survey, all plants use a small amount of fat as additional biomass, but just a part of it can be digested by this temperature.[3] Incorrectly selected or varying temperature regime for manure digestion does not provide the maximum yield of gas. Also a lack of quality insulation of the reactor makes it necessary to spend more energy for the heating.

Problem: Also none of plants have insulated roof of their digesters, which leads to a heat loss.

Solution: For the manure digestion a thermophilic regime with higher temperature (50-52°C) should be chosen[4], unless the heat has a high alternative value, and the digester tank in any case be properly insulated, also the roof (Figure 5). At this temperature more fats can be decomposed with twice less retention time. The retention time during the mesophilic process is above 25-30 days. The thermophilic process can reduce it up to 15 days.[5]

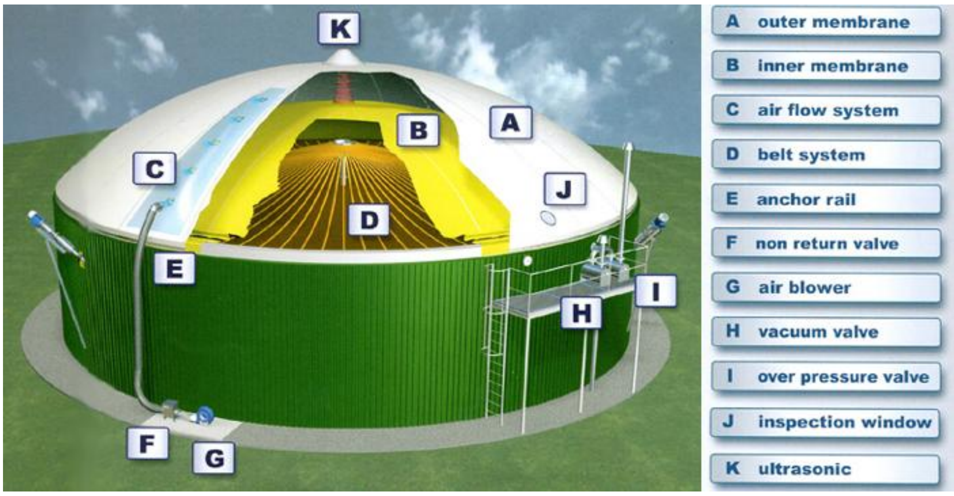

Figure 5: Anaerobic digester covers (source: Carter, 2012)

[3]Based on: Shalanda, 2011
[4] Based on: PJorgensen, Biogas – green energy, 2009
[5] Based on: Navickas, 2007

Saving the heat energy and stabilization of the temperature of the reactor is made possible by an increase of the insulation layer till 20 cm.

Subject: **Admixtures of gas**

Problem: Another problem, which was not recognized during the planning process, is the high level of hydrogen sulphide (H_2S) forming during the process. The corn silage has low sulphure content and the biogas from it only contains little H_2S. The problem is the level of H_2S in plants reaches 1,500-2,000 ppm, what is dangerous for engines.

Solution: It is possible to reduce the amount of H_2S by biological biogas scrubbers. Biogas H_2S scrubbers are used to reduce the content of hydrogen sulphide (H_2S) in biogas and landfill gases providing a cleaner and less corrosive gas for engine combustion. The content of H_2S in the raw biogas can range from 1000 ppm up to 50,000 ppm and under combustion will convert into sulphuric acid leading to severe corrosion of the engine and a considerable reduction in its operational life. Income will be lost during overhauls and break downs which will also require substantial expenditures. The leading gas engine manufacturers can specify a max. 250 ppm H_2S in the biogas to enable full warranty's to be provided. The biological H_2S scrubber can meet these requirements and even better with any flow volume and H_2S content of raw biogas. The H_2S scrubber will reduce H_2S levels to an absolute minimum and is an essential part of the engine life providing operating stability, reliable and economical operation.[6]

Another possibility is to reduce the hushing time in the secondary digester. This allows creating a swimming layer where bacteria can sit and digest H_2S molecules. The rarely mixing of this layer will update bacteria.

Subject: **Ecology and environment**

It was the impression, that all visited biogas plants had a low awareness of potential negative environmental impacts of the biogas production. None of them monitors the emission of gases, sewage discharges and manure management in practice, although all applicable documents are available.

Since 2012 Belarus shall enter the Kyoto Protocol.[7] And building of Biogas Plants in the Republic is an important step reducing emission of carbon dioxide into the atmosphere. With the potential of the plants to produce above 10 mln m^3 of biogas per year, the potential reduction of CO_2 will be more than 22 000 t/year (Figure 5).

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[6] Based on: Biogas products Ltd UK, 2011 (H_2S scrubber description, pdf) (www.biogasproducts.co.uk)

[7] Based on: A. Grebenkov Kyoto Protocol and its mechanisms

Name of Plant	Biogas production mln m^3/year	Real CO_2 reduction t/year	Potential CO_2 reduction t/year
Zapadny	1,8	3546	3714
Belorusky	0,6	600	1236
Zazerye	0,9	0	2217
Snov	7,4	11876	14974
Total	10,7	16023	22141

Figure 5: Annual biogas production and CO_2 reduction using animal manure.
Assumptions:

- Data about biogas production was taken from farms
- "Zazerye" Plant has not worked yet. Thus the biogas production and CO_2 reduction are potential data
- Maximum CO_2 replacement per 1kWh: 730 g
- Energy production from m^3 of gas with 65% methane: electricity production 2.5 kWh/m^3, heat production 3.5 kWh/m^3.

Problem: Greenhouse gas emission from digestate

One of the high risks for the environment arises from digestate due to ammonia emission in to the Atmosphere. The manure has a good quality after the process, because the nitrogen is mineralized and plants may easily absorb it in a short period, alike nitrogen in mineral fertilizers. But all farms have open lagoons without cover to prevent emission of ammonia. Thereafter the digested manure is discharged.

Almost all Biogas Plants don't use the digestate as fertilizers in general or use it not in a correct way. For example, plants A, B and D don't use digestate in plant absorption period. These plants put fertilizers to fields during the year. Plant C transfers fertilizers back to the farm once per month.

Solution: To prevent nitrogen emission it is necessary to cover bottom and surface of the lagoon with a membrane (Figure 4).[8] Another solution is to design a plant with a steel storage for fertilizer which has the same function as lagoon but is more reliable and durable.

[8] Based on: article of AGROBASE Slurry Lagoons. Complete solutions from stable to lagoon. (www.millage.dk)

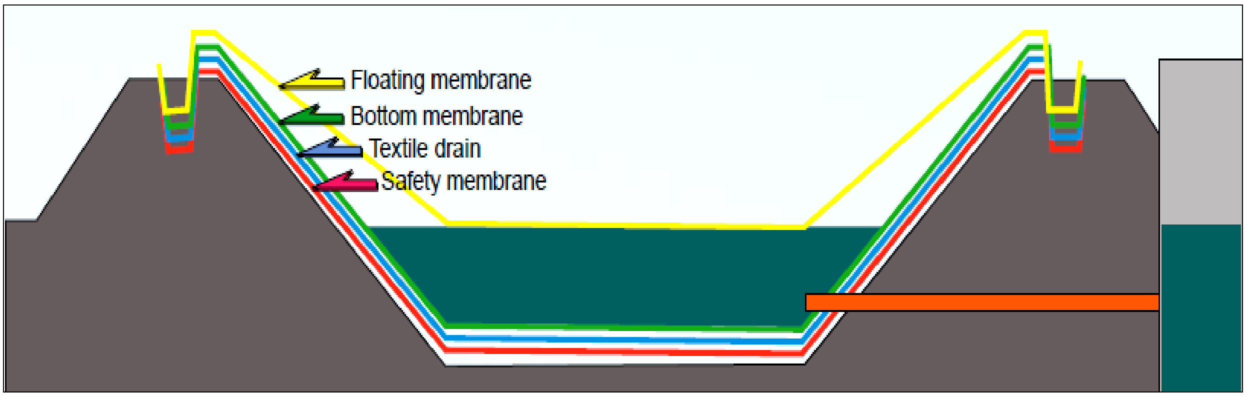

Figure 4: Structure of simple slurry lagoon. Safety membrane, textile membrane and bottom membrane are created to prevent any leakage of slurry into the ground water. Floating membrane can prevent emission of ammonia, to protect out of rain, to reduce odour (source: AGROBASE Slurry Lagoons).

Subject: **Economy and Policy**

Another interesting way of analysis is Economy and Policy inside of the country. According to the Belarusian government 38 biogas energetic complexes should be built with a total power of 38 MW by 2015. For today (2012) just 10 Biogas plants are running and 6 of them are located in agricultural sector, but none of them works in full power.

Problem: Investment capital

The main challenge for the development of Biogas Plants is investment capital. Based on the regulation of the Council of Ministers, a Planning Programme for the financial resources exists, binding 75% of foreign investments. However, as shown in practice, the EU companies don't hurry up to make this step. And if they do, the price for design and construction become 2-3 times higher than in EU, because of high risks.

Solution: Belarusian government has already made some helping steps to stimulate interests of local farmers. For instance: in 2007 three Pilot biogas projects were started up totally on government investments. The idea was to show the working process in reality. As a second step, the price for the green energy had been increased (today the coefficient is +1,3 Euro cent to a standard price). As a third step, agricultural farms can buy electricity from a public grid for a lower price (-2 Euro cent out of standard price). However the situation is that bank credits have high interest rates (40%), deteriorating the profitability of investments.

Conclusion

The research has shown that the potential of biogas production is very high, also because of the ideal situation with the livestock production gathered at large farms, and people are interested in development of it in Belarus. Also there are national investors who would like to go into biogas development, but they hesitate because the results of running biogas projects are not good yet.

One of the main solutions for the Belarus Republic is to improve their education in this sphere. The idea of it is that in the country local specialists with international experience and good knowledge about biogas must be available.

Another important aspect is that Belarus has a huge potential to construct biogas plants on basis of domestic production. There is zinc and steal industries which can produce all equipment for biogas plants and this possibility can reduce costs for the purchase and transportation.

It must be noticed that correct planning could avoid many problems, too. In this case it means a good communication and understanding between contractor, client, government, and all others. All information must be provided in real numbers and in time. One important step in planning is correct independent assessment. The procedure of building is the last step of it.

In this case all problems are related to each other, and one taken decision can avoid other problems.

Acknowledgments

This report would not have been possible without the support of many people. I thank my supervisor Prof. Dr. Uwe Rammert who offered this mission, and many thanks for his patience. The mission would simply not exist without the LLUR Schleswig-Holstein cooperation and support. I want to express my appreciation to the Lars Baadstorp, biogas expert. He improved my knowledge as an expert on biogas production during this week. Special thanks to Henning Lyngsø Foged, the WP4 leader. Without him I would not be involved in the biogas expert group.

I would like to express my gratitude to the Belarusian side, represented by Nikolaj Kapustin, who provided good facilities for mission, very interesting visits of biogas plants, important meetings and Belarusian documents.

Thank you very much to representatives of companies, who provided all data for this report.

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Web-pages:

- www.balticcompass.org/index.html

- www.millage.dk

- www.biogasproducts.co.uk/treatment/index.php

Annex A

General information	
Name of Plant	
Location	
Power (kW)	
Biogas (m^3/day)	
Electricity (MW)	
Thermal energy (MW)	
Design of Plant	
Tank (capacity; how long biomass stay in storage/month)	
Digester (size; horizontal or vertical)	
Heat system for reactor	
Hashing system (days)	
Hydraulic retention time	
Gas cleaning (от примесей)	
Gas engine (quantity, types)	
Electro generator (power) kWh	
Thermo generator (power) kWh	
Storage (size)	
Separation of digested biomass	
Separation of untreated biomass	
Biomass	
Amount t/day	
Cattle manure t/day	
Pig slurry t/day	
Chicken t/day	
Additional waste	

Livestock number	
Technological process (process parameters)	
Temperature	
pH (acidity)	
Comminution	
Carbon-Nitrogen ratio	
Inhibitor	
Antibiotics	
Biogas	
Biogas m^3/day	
Biogas utilization (Biogas upgrading; burning; cogeneration) m3/day	
Admixtures (H_2S; …)	
Cogeneration	
Electro generator, kWh	
Input of gas m3/h	
Output of electricity kWh/m^3	
Output of thermal energy kWh/m^3	
Thermo generator, kWh converts heat to electical energy	
Heat for other purposes	
Ecology	
g CO_2 reduction per m^3 of gas	
N_2O reduction (kg/m^3)	
CH_4 reduction (kg/m^3)	
Total reduction per year	
Nutrient utilization digested and untreated slurry (t/year)	
Nutrient losses N (kg)	
Nutrient losses P (kg)	

Nutrient losses K (kg)	
Degradation of pollutants after the process	
Decontamination of slurry (bacteria, virus, parasites, weed seeds)	
Weed seeds	
Salmonella	
Streptococci	
Separation of digested biomass	
Toxic residues (do they have or no?)	
Infrastructure	
Populated area (how is it far away?)	
Kinds of infrastructure	
Transport	
Gas transport	
Public grid	
Heat transport	
Fertilizer transport	
Biomass input from other places	
Toxic residues	
Economy, Finance	
Costs	
Benefits	
Price for electricity kW/h	
Distribution of income (%) electricity, heat, fertilizers	
Distribution of outcome ()	
Subsidy from government	

Annex B

General information (Biogas Nord) 2005 year	1
Name of Plant	Zapadny
Location	Brest region
Power (kW)	520 kW= 340kW+180kW
Biogas (m^3/day) 4992 m^3/day	208 m^3/h
Electricity (MW) 11,2 MW	12,5 (4992 m3/day*2,5kW=12480 kW/day)
Thermal energy (MW) 15,5 MW	17,5 (4992 m3/day*3,5kW=17472 kW/day)
Design of Plant	
Tank (capacity)	300 m^3
Digester (vertical)	1500 m^3 * 2 (with volume of gas 400 m^3)
Heat system for reactor	Thermo isolation is 8-10 cm around the primary digester; heating system is located also in the bottom (problem: sand)
Hashing system 3	Every hour 2 mixers hush during 10 min (13kW/h) 1 mixer hushes during 5 min (10kW/h)
Retention time	30 days
Gas cleaning	Out of H_2S $+O_2$ =5%
Gas engine (quantity, types)	MAN 2G Energotechnic (Germany)
Electro generator (power) kWh	Stamford
Thermo generator (power) kWh	no
Storage (size)	250 m^3 /transit system
Separation of digested biomass	no
Separation of untreated biomass	Yes (then solid fraction goes to Biogas plant; liquid goes to lagoon)
Biomass (they can use pig manure just from 3 farms out of 40, because other manure has low quality)	
Amount t/day	90 t/day
Pig slurry = 83 t/day	Separated solid pig manure = 40 t/day (with dry matter content 20%) Liquid pig manure = 40 t/day (6% dry matter)

Husk = 3-4 t/day	
Fish waste	1,5 t/day
Slaughterhouse waste	1,5 t/day
Chicken t/day	no
Cattle manure	no
Livestock number	5500 cattle heads – but manure from them do not used for Biogas Plant; 90 000 pigs heads, where 5000 are sows
Technological process (process parameters)	
Temperature mesophilic	37-39° C. last winter was 34,5-35° C
pH (acidity)	7,4-7,9
Comminution equipment	no
Dry matter content in primary digester	10%
Inhibitors	-
Biogas	
Biogas m^3/day	4992 m^3
Biogas utilization (Biogas upgrading; burning; cogeneration) m3/day	All for electricity production
Admixtures (H_2S; …)	H_2S = 300 ppm (probably more, because their equipment doesn't work)
Cogeneration [9]	
Electro generator, kWh	340 kW + 180kW
Input of gas m3/h for 2 generators	208 m^3/h
Input of gas m3/day for 2 generators	All biogas 4992 m^3
Output of electricity kWh/m^3	1m^3=2,5 kW
Output of thermal energy kWh/m^3	1m^3= 3,5 kW
Thermo generator, kWh converts heat to electical energy	no
Heat for other purposes	They use all heat for them self (to heat digesters; to heat water for animals and people; to heat farms)

[9] This paragraph based on calculations of Nikolay Kapustin

Ecology	
Reduction of CO_2	3735 t/year[10]
Nutrient utilization digested and untreated slurry (t/year)	All manure goes to lagoon and then in 3 ponds with biological cleaning
Nutrient losses N (kg)	Huge losses of NPK, because they use open lagoon
Nutrient losses P (kg)	Don’t measure
Toxic residues	They don’t do any analysis, they don’t have any equipment and specialists
Infrastructure	
Populated area (how is it far away?)	In 6 km
Transport	
Gas transport	Natural gas
Public grid	10000 V to public grid
Heat transport	There are isolated pipes under the ground, where hot water is moved to farms, and cold water is coming back
Fertilizer transport (output)	As liquid (open lagoons, then to fields)
Biomass input from other places	no
Economy, Finance (equipment =1,2 mln $ + infrastructure 0,8 mln $)	
Costs	In 2007 = 1,6-1,7 mln euro
Price for electricity kW/h	1 kW=13 cent (they have coefficient 1,3 for the green energy, depend on price for normal energy)
Distribution of income (%) electricity, heat, fertilizers	Electricity – sell 100%; heat – use for themselves; fertilizer – don’t care
Subsidy from government	It was a PILOT Project from government (100% investment capital) + 1,3 coefficient for green energy

Biogas Plant is Pilot Project of Belarus government, to check will it work in Belarus farm or not.

Problems:

1. In the beginning they had problem with H_2S (it was more than 2000 ppm)
2. Winter problems (because of low temperature and high moisture content)
    - Biomass was frosted storing outside
    - Equipment to measure gas had the same problem

[10] According to the Lars type calculations

Annex C

General information Biogas Nord	PILOT Project from Government 2008 2
Name of Plant	Belorusky (poultry farm)
Location	Zaslavl' region
Power (kW)	340 kW
Biogas (m^3/day)	They still use natural gas because they don't produce enough biogas for the engine
Electricity (MW)	3
Thermal energy (MW)	4,5
Design of Plant (the same with Zapadny)	
Tank (capacity; how long biomass stay in storage/month)	300 m^3 + 1 mixer
Reactor (vertical)	1500 m^3 *2
Heat system for reactor	Thermo isolation is 8-10 cm around the primary digester; heating system is located also in the bottom (problem: sand)
Hashing system 3	Every hour 2 mixers hush during 10 min (13kW/h) 1 mixer hushes during 5 min (10kW/h)
Hydraulic retention time	16 days –primary digester; 16 days – secondary digester
Gas cleaning	H_2S; water content
Gas engine (quantity, types) 2	1 engine doesn't work; second uses natural gas+biogas
Electro generator (power) kWh	
Thermo generator (power) kWh	no
Storage (size)	300 m^3
Separation of digested biomass	no
Biomass (real = 57 t/day)	
Among t/day	Potential = 80t/day (9% dry matter content)
Cattle manure t/day	27t/day
Pig slurry t/day	no
Chicken t/day 24	Liquid chicken manure = 10t/year (24,7% dry matter content) Solid chicken manure = 20t/year (24,7% dry matter content)

In 2008 they used corn silage and they didn't have any problems with H_2S	
Technological process (process parameters)	
Temperature	40° C
pH (acidity)	-
Comminution	No. **But they would like to buy grinding machine**
Biogas	
Biogas m^3/day	
Biogas utilization (Biogas upgrading; burning; cogeneration) m3/day	100% for electricity sale
Admixtures (H_2S; …)	H_2S = 170-180 ppm
Cogeneration	
Electro generator, kWh (2 engines)	1- Doesn't work
Heat for other purposes	**They don't use heat at all**
Ecology	
CO_2 reduction	
CH_4 reduction	-
N_2O reduction	-
Nutrient utilization digested and untreated slurry (t/year)	To open lagoon, then to fields
Nutrient losses N (kg)	-
Nutrient losses P (kg)	-
Nutrient losses K (kg)	-
Separation of digested biomass	no
Infrastructure	
Populated area (how is it far away?)	Far away
Transport	
Gas transport	Natural gas
Public grid	All electricity moves to public grid

Heat transport	no
Fertilizer transport	To fields
Biomass input from other places	no
Economy, Finance	
Costs	-
Price for electricity kW/h	1,3 koef. for the green energy
Distribution of income (%) electricity, heat, fertilizers	100% of electricity
Subsidy from government	100% investment capital from Government as Pilot Project

They would like to buy a centrifuge to separate pig manure from 36 farms, and therefore to have more solid manure.

They would like to increase input of dry matter content

Problems:

1. Sedimentation of primary digester. They clean it every 2 years. They don't have pump between digesters.
2. Heating system is useless on the bottom of digester because of sedimentation
3. H_2S limit = 180 ppm
4. Sand is accumulating in to the Storage Tank (volume = 300 m^3). They stop the process and clean it.

Annex D

General information PILOT Project, it doesn't work yet	3
Name of Plant	Experimental base "Zazerye" (Institute cattle farm)
Location	Zazerye village, Pukhovicheskiy district
Power (kW)	250
Biogas (m^3)	100 m^3/hour
Electricity (MW/day)	5,5
Thermal energy (MW/day)	6,8
Design of Plant	
Tank (capacity)	104 m^3
Digester (vertical)	Primary -1600 m^3 (with volume of gas 136 m^3) Secondary -1736 m^3
Heat system for reactor	Thermo isolation is 8-10 cm around the primary digester; heating system is located on walls and also in the bottom (problem: sand)
Hashing system 3	Every hour 2 mixers hush during 10 min (13kW/h) 1 mixer hushes during 5 min (10kW/h)
Retention time	24 days *2 digesters = 48 days
Gas cleaning	Air supply to the digester, max 76 m^3/h
Gas engine (quantity, types)	ETW 250 BG
Electro generator (power) kWh	250
Thermo generator (power) kWh	no
Storage (size)	2*4000 m^3, + 2 lagoons
Separation of digested biomass	no
Separation of untreated biomass	Expeller-separator, model: PSS3.2 - 520
Biomass	
Amount t/day	74 t/day
Cattle manure liquid	65 t/day (10 % dry matter content)
Cattle manure solid	7 t/day (25% dry matter content)
Straw material	2 t/day (18% dry matter content)
Livestock number	-
Technological process (process parameters)	

Temperature mesophilic	38-42° C
pH (acidity)	-
Comminution equipment	yes
inhibitors	no
antibiotics	no
Biogas	
Biogas m^3/day	2400 m^3
Biogas utilization (Biogas upgrading; burning; cogeneration) m3/day	All for electricity production
Admixtures (H_2S; …)	Don't have this problem yet, because this farm doesn't run yet 55-65% CH_4, 35-45% CO_2, 100-500 ppm H_2S, > 1% O_2
Cogeneration	
Electro generator, kWh	250
Input of gas m^3/h	100
Input of gas m^3/day	2400
Output of electricity kWh/m^3	1m^3=2,5 kW
Output of thermal energy kWh/m^3	1m^3= 3,5 kW
Thermo generator, kWh converts heat to electical energy	no
Heat for other purposes	They plan to use 20 % of heat energy for the digester + other energy transport to the cattle farm
Ecology	
Reduction of CO^2	Potentially = 2217 t/year
CH_4 reduction	Not measured
N_2O reduction	Not measured
Nutrient utilization digested and untreated slurry (t/year)	All manure will be moved to lagoons
Nutrient losses N (kg)	Not measured
Nutrient losses P (kg)	Not measured
Nutrient losses K (kg)	Not measured
Infrastructure	

Populated area	Village in 1 km
Transport	
Gas transport	To gas engine (about 50 m)
Public grid	All energy move to the public grid of Belarus
Heat transport	To the cattle farm (100 m)
Fertilizer transport (output)	To fields
Biomass input from other places	no
Economy, Finance	
Costs	About 3 mln euro
Price for electricity kW/h	1 kW=13 cent (they have coefficient 1,3 for the green energy, depend on price for normal energy)
Distribution of income (%) electricity, heat, fertilizers	Electricity – sell 100%; fertilizers and heat – don't care
Subsidy from government	1,5 mln euro from government + 1,3 coefficient for green energy

The idea of this Biogas Plant was just to check will it work in Belarus farm or not.

The Biogas Plant will start to run in December of 2012.

Problems:

1. Digesters are not covered
2. Lagoons are not covered
3. They will not collect gas from secondary digester
4. Like all farms they don't use the pump between digesters
5. They don't have any money to change the design

According to Baltic Compass Project they will cover Digester and Lagoon

Annex E

General information “TDF Ecotech AG” December 2011 (100% of own investments)	4
Name of Plant	TDF Ecotech Snov
Location	150 km from Minsk, Snov village
Power	2 MW = 1 +1
Biogas (m^3)	840 m^3/h
Electricity (MW)	20 MW (from January to March they have produced 1000 MW)
Thermal energy (MW)	47,7 MW
Design of Plant	
Tank (capacity)	200 m^3
Digester (**vertical**)	2600 m^3 * 4 Primary (with total volume =10400 m^3) 2600 m^3 * 3 Secondary
Heat system for reactor	Heat on walls and on the bottom of digesters
Hashing system 3	Every hour 2 mixers hush during 10 min (13kW/h) 1 mixer hushes during 5 min (10kW/h)
Retention time	22 days (primary) +23 days (secondary)
Gas cleaning	Out of H_2S (air supply to the digester)
Gas **engine** (quantity, types)	Jenbacher j416 GS
Electro generator (power) kWh	1050*2
Thermo generator (power) kWh	no
Storage (size)	-
Lagoon	14500 m^3 have not used yet **(open)**
Separation of digested biomass	no
Separation of untreated biomass	no
Biomass (potentially =460 t/day)	
Amount t/day	427,7 t/day
Pig slurry	221 t/day (liquid, dry matter content = 4%)
Cattle manure	148 t/day, (dry matter=16%) (Without bedding. There is new Canadian technology

	to use sand material instead of straw)
Chicken	24 t/day
Corn silo	8,2 t/day (dry matter = 35-45%)
Chopped straw	10,9 t/day (dry matter = 14%) (they use straw as additional biomass to mix with cattle slurry (liquid).
Hay	1,1 t/day (dry matter 15%)
Slaughterhouse waste	11,5 t/day (dry matter 18%)
Technological process (process parameters)	
Temperature mesophilic	35-40° C
pH (acidity)	6,8 - 8
inhibitors	no
antibiotics	no
Comminution equipment	Yes, but there are equipment just for corn silo. It is not enough to grind straw materials.
Biogas	
Biogas m^3/day	20160
Biogas utilization (Biogas upgrading; burning; cogeneration) m^3/day	All for electricity production
Admixtures (H_2S; …)	55-70% CH_4, 30-45% CO_2, 100-500 ppm H_2S, > 1% O_2
Cogeneration	
Electro generator, kWh	1050*2
Input of gas m^3/h	840
Input of gas m3/day	20160
Output of electricity kWh/m^3	$1m^3$=2,5 kW
Output of thermal energy kWh/m^3	$1m^3$= 3,5 kW
Thermo generator, kWh converts heat to electical energy	no
Heat for other purposes	They use all heat for themselves 15 %; + from December to march – for farm?
Ecology	

Reduction of CO_2	Potential = 15,5 mln t/year
CH_4 reduction	-
N_2O reduction	-
Nutrient utilization digested and untreated slurry (t/year)	Have not done it
Nutrient losses N (kg)	Chemical content of digested slurry: (N) = 4.4 kg/m^3; (NH_4-N) = 2.6 kg/ м^3; (P_2O_5) = 1,9 kg/ м^3; (K_2O) = 5,0kg/ м^3
Nutrient losses P (kg)	
Nutrient losses K (kg)	
They don't do any analysis for decontamination of slurry	
Infrastructure	
Populated area	In 1 km
Transport	
Gas transport	To gas engine (about 50m)
Public grid	100% of all electricity is transported to public grid
Heat transport	There are isolated pipes under the ground transporting heat to pig farm
Fertilizer transport (output)	As liquid (open lagoon, then to fields)
Biomass input from other places	no
Economy, Finance	
Costs	6,8 mln euro
Price for electricity kW/h	1 kW=13 cent (they have coefficient 1,3 for the green energy, depend on price for normal energy)
Distribution of income (%) electricity, heat, fertilizers	Electricity – sell 100%
Subsidy	95% investment capital from EU concern (TDF Ecotech, +5% Agrocomplex Snov) + 1,3 coefficient for green energy (from government)

Problems:

1. The farm doesn't fulfill the contract of supplying enough biomass.
2. There are problems with feeder-machine, because biomass (cattle manure +straw) has long straw material, sand content, sticks. So, is clogging of feeder.

They would like to buy a grind machine