

Summary Report of LEI

WP3 “Policy tools and aids at local level”

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Summary Report of LEI (LSR)

Objective

This document is a summary of a more extended feasibility study regarding bio-gas, bio-gas extraction technologies, the types of the bio-gas formation processes from the organic waste. This Study includes the brief review on the bio-gas plants operating in Lithuania, legislation and description of the possible production potential.

Role and relevance for project:

This feasibility study is needed in order to evaluate the actual situation and to establish the strategy and approach for a bio-gas case study proposal in Lithuania. This document is a final draft of that analysis.

The original proposal has been abandoned for new information that came available during the project activities revealed a very scarce environmental savings result.

Role and relevance for targeted readers:

The document explains the advantages of the use of bio-gas plants in pig farm.

Target groups:

SME's (pig-farmers), Local decision makers, Advisory Group, External contacts

TECHNICAL - ECONOMICAL AND ECOLOGICAL STUDY ON BIOGAS UTILIZATION FOR ENERGY PURPOSES

SUMMARY

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Introduction

The Treaty of accession to the European Union anticipates that the economical development must be based on the environmental criteria. Lithuania, as a member of European Union, is obliged to follow legal acts of EU which regulate the development of the energy sector.

The National Program regarding increase of efficiency of energy consumption anticipates the rapid usage of the local and renewable resources. Following the requirements of EU, Lithuania strives for a share of renewable energy resources of up to 12% in the total primary energy balance by 2010. The production and usage of the renewable energy resources are considered as priority areas in the development of the energy sector.

The huge amounts of waste comprises at the enterprises for production of the agricultural products and alimentary products which must be properly handled and usefully utilized. The organic waste can be used for feeding, digesting. Also the waste can be burned or ploughed in the fields or processed into bio-fuel or bio-gas. The current Study analyses the possibility to process the organic waste from pig farms and butchery to the bio-gas.

The Study introduces the summarized theory about bio-gas, bio-gas extraction technologies, the types of the bio-gas formation processes from the organic waste. This Study includes the brief review on the bio-gas plants operating in Lithuania, legislation and description of the possible production potency. The Chapter 5 includes the Feasibility Studies of the bio-gas plants' implementation at the different stockbreeding complexes. The Chapter 6 includes the economical assessment of the expedience of the bio-gas plants' implementation at the particular object. The conclusions include the summation of the further bio-gas utilization for the energy purposes in Lithuania in accordance with the Feasibility Studies mentioned above.

1. The summation of the bio-gas production potential in Lithuania

The strict environmental requirements have conditioned the development of bio-gas production in all EU countries. The bio-gas received during anaerobic decomposition of the organic waste can be utilized as energy source for electricity and heat generation or as gas fuel. The one of the main raw material sources for biogas production in Lithuania is livestock manure. Therefore the development of the biogas energy sector is related to the current condition and future of the country's stockbreeding.

Stockbreeding and poultry enterprises. Following the statistics information the number of livestock at Lithuanian farms has stabilized and has a tendency to increase because Lithuania received the better quota for meat and milk production comparing to present production. The pig farms which have the biggest production potential are modernized and expanded.

The possibilities of stock and poultry manure utilization for the production of biogas depends on different factors: the size of farm, the way of stock and poultry keeping, manure handling technology, composition, the demand for energy. Therefore the best future for the biogas plants' construction has the large farms using the modern technologies and considerable demand for heat energy (the farms where the number of stock - 200 and more, the number of pigs - 5000 and large poultry farms).

The butcheries and meat processing enterprises which have been striving to receive licenses have been modernized and expanded. In that case there comprises about 60 thous. t of animal waste which can be processed at biogas plants. And there can be extracted about 12 million m³ of biogas, which energy value amounts approx. 70 GWh.

Presently two animal waste processing enterprises are operating in Lithuania. But they cannot afford to process this amount of animal waste. On the other hand it is not economically purposive to transport all organic waste from the butcheries located all over the country. Much more economically to expand the biogas production near the butcheries and to use the produced heat energy not only for the own needs of enterprises, but also for the thermal treatment of waste.

Landfills. About 1 million t of waste appears in Lithuania every year. In country there more than 800 landfills including 300 in operation. 680 landfills are small (smaller than 1 ha), 120 - are of average size (1-5 ha) and 35 - large (more than 5 ha). In the largest cities of Lithuania there compose about 300 kg/year of waste for 1 inhabitant, in the smaller towns - about 220 kg/year, in villages - about 70 kg of waste.

About 44 % of all inoffensive waste goes to landfills [2]. Currently the operating landfills are not well equipped. A big number of landfills are located at the deserted open pits. The waste is not sorted.

The composition of waste in large towns and countryside is different. The data in the table No. 1.1 shows that in the flow of the waste of large towns dominates biologically decomposed waste (about 50 ± 5 %), meanwhile in country side only 33 ± 5 %.

1.1 table. Waste distribution according groups, %

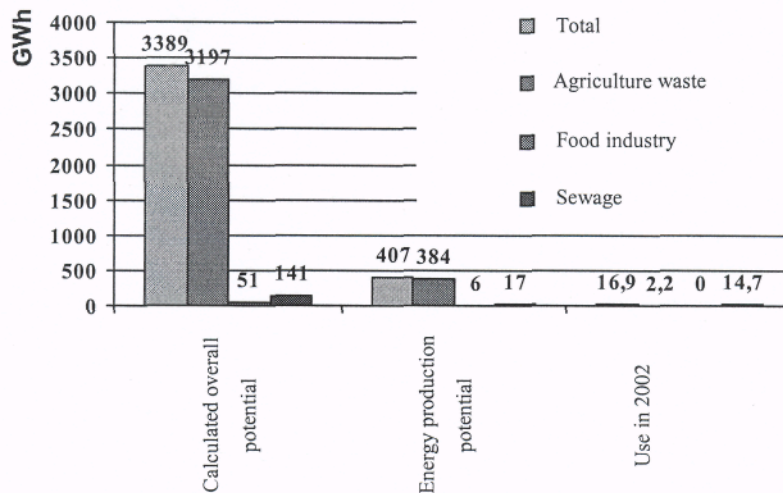
| Waste flow in the centres of the Municipalities | Waste flow in the district | Waste flow in the countryside | Waste group Municipalities |
|---|----------------------------|-------------------------------|----------------------------|
| biologically decomposed waste | 50±5 | 50±5 | 33 |
| + 5 paper waste | 17 ±5 | 20 ± 5 | 15 + |
| 5 plastic waste | 7,5 ±2 | 7,5 ±2 | 10 + 2 |
| glass waste | 8,5 ±2 | 7,5 ± 2 | 12 ±2 |
| metal waste | 2 ±1 | 2 ±1 | 2 ± 1 |
| other combustible waste | 6+1 | 6+1 | 8 ± 1 |
| other incombustible waste | 9±2 | 7±2 | 20 ±2 |

Assessing the total amount of waste (approx. 1 mln. t per year) we can state that the potential of biologically decomposed waste amounts to 0.3 - 0.5 mln. t per year. Such waste, separated from the other sort of the waste, could be utilized for the energy generation. It is possible to extract about 15-20 mln. m³ of biogas from the mentioned amount of the waste, which energetic value amounts to approx. 100GWh.

Sewage. In 2002 the country's sewage treatment and outlet system included 967 units of treatment equipment. According Environmental Protection Agency's information about 170.4 mln. m³ of sewage has been discharged in the Lithuanian towns and countryside. 46,8 % of sewage has been treated partly (in biological and mechanical treatment equipment), 14,6 % - treated partly only in mechanical way, 37,9 % - fully treated (with additional removal of nitrogen and phosphorus). 0.6% - has not been treated. Though there has been constructed or reconstructed sewage treatment equipment the amount of the discharged sewage in many towns reduced for 5 times comparing to 1990, however the discharge of the organic waste still amounts to 6-7 t and to 3-4 t per year of biogenic materials. In many towns the waste treatment does not satisfy the EU requirements.

The different biogas production Studies indicates [3-7], that theoretic potential is considerable.

It should be possible to generate more than 3000 GWh of energy if overall amount of organic waste is processed. However according assessment of the real possibilities of processing and economical indicators the potential should amount to 300 - 400 GWh of energy.



1.1 picture. Potential of energy production from biogas

2. Examples in operation: implemented technologies, description of positive environmental and economical efficiency, problems

The biogas energy sector in Lithuania has been developed since 1994. Currently six biogas plants are in operation: in Kaunas and Utena cities, which process the sewage sludge, AB "Sema" and AB "Rokiskio suris" - process the waste of food industry, ZUB „Vycia" and UAB „Lekeciai" -process the live stock manure and waste from food industry enterprises. The biogas plants at AB "Rokiskio suris" and UAB „Lekeciai" started its operation in 2003.

The total capacity of the bioreactors installed at Lithuanian biogas plants amounts to 16 thous. m³. All plants are able to process about 350 thous. t/year of organic waste. The total energetic capacity of biogas plants amounts to 15.5 MW, including 14 MW of heat and 1,4 MW of electricity.

In 2002 four biogas plans generated 22 GWh of heat and electricity energy.

2.1 table. Lithuanian biogas plants' indicators.

| Indicator | B | A "op vandenvala | Kaun s vandenvala | Uteno s vandenvala | Z UB "Vycia" | UA "Le suris" | AB "Rokiskio suris" |
|------------------------------|-----|------------------------|----------------------|-----------------------|--------------------|---------------------|---------------------------|
| Reactor size, m ³ | 000 | 3 | 10000 | 2x10 00 | 3 x300 | 2000 | 800 |
| Heat capacity, MW | 1 | 7 | 3.8 | 0.44 | 0. | 1.2 | 0.6 |
| Electric capacity, MW | | - | - | 0.275 | 0. 185 | 0.6 | 0.33 |
| Annual production, GWh | | | | | | | |
| Electricity | | | | 0.77 | 50 | * | * |
| Heat | 32 | 4 | 12.6 | 1.54 | 1. 95 | * | * |

*No information

The bio gas plants at the water treatment enterprises have been constructed on the funds of towns budgets and different environmental programs. At the Kaunas water treatment plant there is installed only gas boiler plant, therefore there has emerged the excess of generated

biogas, which has been supplied to LZUU boiler plant. In 2005 five units of CHP, each capacity 150 kW_{el}, was installed at the boiler plant.

AB „SEMA" has constructed biogas plant on its own funds. The biogas reactor has processed the waste from the alcohol production - grain. The biogas has been burned in the gas boilers, and generated heat has been used for alcohol production and heating of premises. However currently the alcohol production is stopped and bio gas production is stopped as well. Some equipment has been demounted.

AB "Rokiskio suris" has constructed its plant striving to reduce the amounts of production waste and expenses necessary for their processing. The biogas reactor processes the enterprise's waste -whey. The processing of whey is rather complicated due to big acidity and chemical impurity. However after the adaptation period the biogas plant's operation has stabilized. The produced gas is burnt in CHP.

The demonstrational biogas plant at ZUB "Vycia" started its operation in 1998. It is the first enterprise for processing of agricultural waste for heat and electrical energy. [8, 9]. Its construction has been supported by the Denmark Environmental and Energy Ministry, which covered 88 % of construction expenses (approx. 2,5 mln. Lt). ZUB "Vycia" has invested the rest part. The operation of biogas plant has been stopped for reconstruction after the fire at the CHP room in 2004. The fire gas damaged CHP and its control system.

The biogas plant at UAB "Lekeciai" has been constructed on the Company's own funds. The plant processes the pig manure from the locally pig farms, food and feed plants . The processing of mentioned waste is complicated due unstable and big concentration of protein and grease which cause troubles in biological process. The generated heat is used for heating of stables, production buildings. The generated electricity is used for own need and surplus is supplied to the distribution nets.

3. The present problems in stockbreeding sector, utilization of agricultural waste, the limits of environment pollution and EU directives

The huge amount of manure is concentrated at the cattle and poultry farms. The manure is cumulated for 4-6 months at store places and further is used for fertilize. It is impossible to avoid the pollution of the environment even though the storage is executed in accordance with various norms.

The big concentration of manure around cattle and poultry farms contaminate the groundwater with liquid slurry, air with nitrogen compound (NH₃, N₂O), carbon dioxide (CO₂) and methane (CH₄) gas [11].

Many European countries follows strict requirements for stockbreeding buildings, equipment for manure and sludge keeping and fields fertilizing [1, 12-14]. In the Western Europe countries there are required to install storages by the farms, which could contain manure and wastewater from farms for 6-8 months (Denmark - 9). The liquid manure and slurry are contaminated with a lot of various microorganisms and parasite. [15]. Such unprocessed organic fertilizers pollute the environment with microorganisms, and cause pathogenic danger for biofauna. [16]. The pathogenic danger of some microorganisms are able to survive for a long time [17], depending on the environmental factors. One of the way to reduce this risk is the anaerobic processing of liquid manure and slurry. It can be executed by biogas reactor. The liquid manure processed in such way can be used as organic fertilizer and biogas - as the additional source of the energy.

In 2002 there was accepted EU Council Directive 96/61/EC concerning integrated pollution prevention and control, The purpose of this Directive is to achieve integrated prevention and control of pollution arising from the activities at large industrial and agricultural enterprises. The processing of waste for the energy needs is encouraged by the law on Environmental protection of Lithuanian Republic [18] and the rules of the issue of permit for integrated pollution prevention and control [19], Striving to reduce the impact of pollution from stationary economic objects and avoid the downthrow of pollution from one environment to another, the rules claims integrated system of pollution prevention and control which band air, land and waste treatment measures. While implementing these rules it is striving to use rationally the nature resources and energy. In accordance with mentioned rules the permits must receive the certain size cattle and poultry farms, butcheries and food industry enterprises.

The treatment of waste comprised at butcheries, milk and meat processing enterprises is regulated by the rules of handling the animal by - products issued by European Parliament and Council from 3 October 2002 No. 2002/1774 which determines the rules concerning animal by-products, not for people food. The law and rules determine the order of collection, transporting, keeping, handling, processing, and usage of animal by-products to avoid the danger for people and animal health. The rules point that the animal products of 2 and 3 categories can be processed at the biogas plants.

The nature and composition of raw material determines the possibilities of processed biomass usage (for instance - the possibility to fertilize plants). The microbiologically impure waste must be treated before usage.

4. Problems at countryside and small towns, which determines certain energy technologies. The grounding of solution for energy demands and especially for environment handling and reduction of pollution

Presently the pig farms face the problems regarding environmental requirements developing farms operation and increasing the number of pigs. Following the requirements of EU and Lithuanian Republic directives the pig farms must have appropriate area of farmland, depending on the number of pigs at farm, where the slurry could be watered.

This demand is related with the nitrogen amount and concentration limit to the piece of land area. Many pig farms have their own butcheries and incur big expenses related with utilization of pig waste. The amount of utilization expenses depends on pig waste category and amounts to 600 Lt/t.

The biogas production partly shall solve this problem because after anaerobic process in biogas reactor the liquid fraction of the waste is separated from the solid and the nitrogen amount is reduced. Such processed slurry is possible to water in a larger amounts to the same area of the land comparing with slurry directly from the pig farms. Therefore there appears the possibility to increase the number of the pigs at the farm. The farm should be able to receive the additional income if it utilize the waste from other butcheries.

The biggest advantages of the biogas reactor and electricity and heat production as follows:

1. Due to the reduced amount of nitrogen it is possible to water a larger amount of the slurry on the farmland what enables to increase the number of the pigs at the farm;
2. The waste after the bioreactor shall not spread the bad smell, therefore the complaint from inhabitants shall reduce;
3. The sludge after bioreactor can be used for the production of the fertilizer and substratum what enables to introduce the new direction of the business at the farm and create the new workplaces.
4. The expenses for generated electricity and heat energy are equal to bioplant's exploitation expenses, so the price for energy produced from the biogas is lower than receiving it from the distribution nets or produced burning natural or liquid gas. The expenses of production at the farm shall reduce and farms competitiveness shall increase.
5. The additional personnel is necessary for the plant's maintenance, therefore the new work places in the district shall be created.
6. The farms which install CHP has the reserve source of energy what shall reduce the operation downtime at the farm related to energy supply from the distribution nets.

5. The Feasibility Studies at the different farms, assessing infrastructure factors, problems of energy supply, potential of biogas production at the certain farm at the villages and towns

This chapter includes the Survey Feasibility Studies of biogas plants at three different farms without assessment of projects' economical effect. As description includes the confidential information concerning amount of waste, number of stock and poultry the name of farm shall not be disclosed.

5.1 The possibilities of processing the pig manure and butcheries waste to biogas and its utilization for energy purposes at the farm complex in Vilnius district

Place description, problems, current production of heat and electricity

The farm is located in Municipality of Nemencine, Vilnius district. The heat is generated by burning the liquid natural gas. Due to additional expenses while purchasing the fuel the economical indicators of the complex decrease.

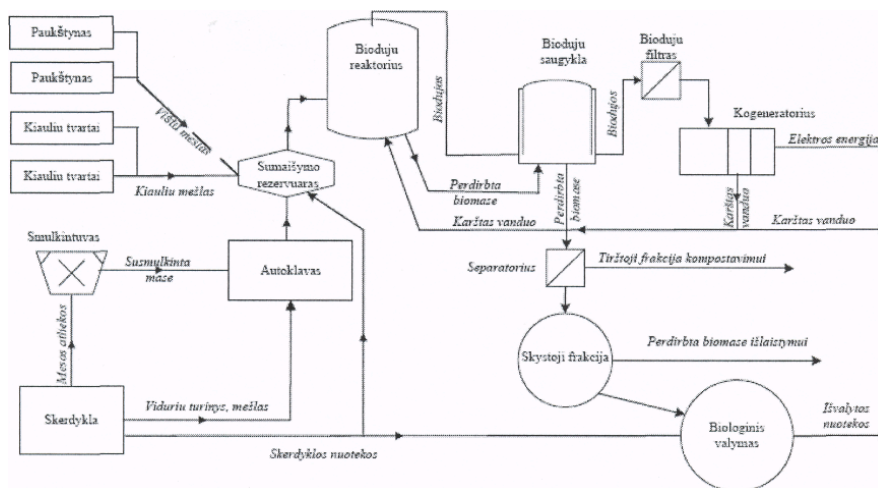
At the farm complex there is 12 thousand of pigs, where annual amount of the liquid manure amounts to 26 thous. t. and annual amount of butchery waste amounts to 900 t, totally - 26900 t/year of waste. Due to comprising so big amounts of the waste it is purposive to produce the biogas.

Summary technological scheme, its description

The technological scheme of the biogas plant, processing the waste of pig farm and butcher, includes the following technological processes:

- Collection of waste;
- Transportation of waste;
- Processing of waste;
- Mixing of waste;
- Biogas production;
- Biogas collection and treatment;
- Biogas burning and energy production;
- Processing of processed waste, storage and utilization.

The principal technological scheme of biogas plant presented below.



5.1 picture. The principal technological scheme of biogas plant

The thick or solid biomass is crushed before mixing with the liquid part of the substrat. For treatment of animal waste there must be installed autoclave.

5.1 table. Summary of main technological equipment of biogas plant at the complex in Vilnius district

| | | |
|---|---|-------------------------|
| Waste tank with mixer | 1 | Iki 300 m ³ |
| Waste crusher | 1 | i 5 t/d |
| Autoclave for thermal processing | 1 | Iki 5 m ³ /d |
| Biogas reactor | 1 | 1800m ³ |
| Tank for processed substrate and biogas | 1 | 300m ³ |
| Biogas filter | 1 | 100m ³ |
| Processed biomass separator | 1 | Iki 80 m ³ |
| CHP block with heat substation | 1 | 150kW _{el} |
| Technological process control equipment | 1 | - |
| Pumps of waste processed and under processing | 6 | - |

Potential of biogas based on calculations

As it has been mentioned above the manual amount of waste - 26900 t/year. It is assumed that concentration of the solid substance (SS) - 6 %. Striving to specify energy indicators of the biogas it should be necessary to estimate the chemical composition of the processed manure and possible amount of biogas.

5.2 table. Organic waste which is possible to process at CHP of complex in Vilnius district

| Sort of waste | Source of waste | | Amou nt (t/day) | Amou nt (t / year) | SS% (calc) |
|------------------|----------------------|------------------|--------------------|-----------------------|---------------|
| | Place, enterprise | Distan ce, km | | | |
| 1. Manure | Pig farm complex | 0 | 72* | 26000 | 6 |
| 2. Butchery's | Butcher | 10 | 3,6** | 900 | 20 |
| Total | | | | 26900 | - |

*Calculated 365 days per year ** Calculated 250 days per year

The composition of butchery's waste has not been assessed. It is necessary to investigate the chemical composition of waste and possible amounts of biogas from the waste. It is assumed in the analysis, that butcheries shall supply the animal waste of 2 and 3 categories. The potential of the biogas production is determined taking into account the specific amount of the biogas with the certain concentration of the solid substance (SS, %). The countable amounts of biogas production is presented in the table below.

5.3 table. The countable amounts of biogas production at the plant in Vilnius district

| Waste | | | Biogas | |
|-----------|--------|-----|-------------------|----------------------|
| Sort | t/year | SS% | m ³ /t | m ³ /year |
| 1. Manure | 26000 | 6 | 20 | 520000 |

| | | | | |
|---------------------|-------|----|-----|--------|
| 2. Butchery's waste | 900 | 30 | 100 | 90000 |
| Total | 26900 | - | - | 610000 |

Calculations of the energy flows, security of energy supply reliability from the plant

It is forecasted to extract the biogas at the plant with concentration of methane - 60 % , and energy value - 6,0 kWh/m³. Burning the biogas in the equipment which efficiency is equal to 0,90 -30 % of this energy is converted to electricity and 60 % - to heat energy. The presumptive amounts of electricity and heat while burning the biogas are presented below in the table.

5.4 table. The design data of the biogas plant at the pig complex in Vilnius district

| | | |
|---------------------|---|-------|
| Capacity | Amount of waste per year, t | 26900 |
| | Amount of waste per day, t | 75,6 |
| Biogas production | Biogas production per year, thous. m ³ | 610 |
| | Biogas production per day, thous. m ³ | 1,67 |
| | Calculated methane concentration, % | 60 |
| | Biogas energetic value, kWh/m ³ | 6,0 |
| Energy production | Total amount of energy per years, | 3,29 |
| | Electricity per year, mln. kWh | 1,10 |
| | Heat energy per year, mln. kWh | 2,19 |
| | Total energy amount per day, thous. | 9,0 |
| | Electricity per day, thous. kWh | 3,0 |
| | Heat energy per day, thous. kWh | 6,0 |
| CHP characteristics | Calculated el. capacity, kW | 150 |
| | Calculated heat capacity, kW | 250 |

Necessary investments

The preliminary demand for the investments was determined in accordance with the principle scheme and selected equipment on the prices of the analogical equipment sold in the markets of Lithuania and EU. More exact prices can be set while preparing the technical project or receiving commercial offers. The total price for main equipment of biogas plant and its construction is presented in the table below.

5.5 table. The price for the biogas technological equipment at pig complex in Vilnius district

| N | Name | A | Characteris | Price, |
|--------|--|---|-----------------------|--------|
| 1 | Waste tank with mixer | 1 | 300m ³ | 40,0 |
| 2 | Crusher and autoclave for animal waste | 1 | 5t/d | 600,0 |
| 3 | Biogas reactors with | 1 | 1800 | 1000,0 |
| 4 | Biogas storage | 1 | 300m ³ | 90,0 |
| 5 | Biogas filters | 1 | 100 m ³ /h | 105,0 |
| 6 | Separator of processed | 1 | 80 m ³ /d | 40,0 |
| 7 | CHP block with heat | 1 | 450 kW _d | 800 |
| 8 | Technological process control equipment | 1 | - | 200 |
| 9 | Pumps station of waste processed and under | 1 | - | 155 |
| Total: | | | | 3030 |

The preliminary price for biogas plant's construction - 3 million Lt. This price doesn't include the prices for buildings, land, ways and engineering nets.

Economical calculations must include the expenses for transportation of the waste from the butcheries.

5.2 The possibilities of processing the pig manure and other organic waste to biogas and its utilization for energy purposes at the complex in Jonava district Municipality

Place description, problems, current production of heat and electricity

The farm is located in Silai village, Jonava district Municipality. The heat is generated by burning the natural gas but due increase of fuel prices the farm incurs bigger expenses.

At the farm complex there is 15 thousand of pigs, where annual amount of the liquid manure amounts to 35 thous. t. and annual amount of butchery waste amounts to 480 t of waste. Due to comprising so big amounts of the waste it is purposive to produce the biogas.

Summary description of technology

The principle scheme of the biogas plant and its description have been presented in chapter 5.1. The main plant's technological equipment and characteristics are presented below in the table.

5.6 table. Summary of main technological equipment of biogas plant at the complex in Jonava district Municipality

| | | |
|---|---|-----------------------|
| Waste tank with mixer | 1 | 500 m ³ |
| Waste crusher | 1 | 10 t/d |
| Autoclave for thermal processing | 1 | 10 m ³ /d |
| Biogas reactor | 3 | 3x1000 m ³ |
| Tank for processed substrate and biogas | 1 | 600m ³ |
| Biogas filter | 1 | 300m ³ |
| Processed biomass separator | 1 | 150m ³ /d |
| CHP block with heat substation | 1 | 500 kW _{el} |
| Technological process control equipment | 1 | - |
| Pumps of waste processed and under processing | 6 | - |

Potential of biogas based on calculations

It is assumed that concentration of the solid substance (SS) in the pig manure - 6 % and concentration of the solid substance (SS) in the poultry manure - 20 % Striving to specify energy indicators of the biogas it should be necessary to estimate the chemical composition of the processed manure and possible amount of biogas.

5.7 table. The amounts of the organic waste for processing in Jonava district Municipality

| Sort of waste | Source of waste | | Amount | | SS% (calc.) |
|---------------|-------------------|--------------|-----------|------------|----------------|
| | Place, enterprise | Distance, km | (t/d day) | (t/y year) | |
| Manure | Analyzed complex | 0 | 96*00 | 350 | 6 |

| | | | | | |
|----------------|------------------------|----|------|-----|----|
| Poultry waste | Gireles poultry farm | 35 | 44** | 110 | 30 |
| Poultry manure | Gireles poultry farm | 35 | 41* | 150 | 20 |
| Butchery | complex + Pauliuku ZUB | 0 | 1,9* | 480 | 20 |
| Total: | | | | 515 | - |

*Calculated 365 days per year ** Calculated 250 days per year

It is foreseen to process about 1100 t of poultry of Girele poultry farm and 480 t of butchery waste. This Study does not estimate the composition of the waste of both butcheries. It is necessary to explore the chemical composition of the waste and possible amount of biogas. The potential of the biogas production is determined taking into account the specific amount of the biogas with the certain concentration of the solid substance (SS, %).

5.8 table. Calculation of biogas production at the bioplant of the complex in Jonava district Municipality

| Waste | | | Biogas | |
|---------------|----------|-----|-------------------|----------------------|
| Sort | (t/year) | SS% | m ³ /t | m ³ /year |
| Manure | 35000 | 6 | 20 | 700000 |
| Poultry waste | 1100 | 30 | 80 | 88000 |
| Poultry | 15000 | 20 | 60 | 900000 |
| Butchery | 480 | 20 | 100 | 48000 |
| Total | 51580 | - | - | 173600 |

Calculations of the energy flows, security of energy supply reliability from the plant

It is forecasted to extract the biogas with concentration of methane - 60 % , and energy value -6,0 kWh/m³ at the designed plant. Burning the biogas in CHP which efficiency is equal to 0,90 - 30 % of this energy is converted to electricity and 60 % - to heat energy. The presumptive amounts of electricity and heat while burning the biogas are presented below in the table.

5.9 table. The design data of the biogas plant at the complex in Jonava district Municipality

| | | |
|-------------------|---|------------------------|
| Capacity | Amount of waste per year, t | 51580 |
| | Amount of waste per day, t | 141,3 |
| | Waste concentration SS, % | 10,7 |
| Biogas production | Biogas production per year, thous. m ³ | 1736 |
| | Biogas production per day, thous. m ³ | 4,76 |
| | Calculated methane concentration, % | 60 |
| | Biogas energetic value, kWh/m ³ | 6,0 |
| Energy production | Total amount of energy per years, mln. | 9,38 |
| | Electricity per year, mln. kWh | 3,12 |
| | Heat energy per year, mln. kWh | 6,26 |
| | Total energy amount per day, thous. kWh | 25,7 |
| | Electricity per day, thous. kWh | 8,57 |
| | Heat energy per day, thous. kWh | 17,14 |
| | CHP characteristics | Total el. capacity, kW |

| | |
|-------------------------|-----|
| Total heat capacity, kW | 900 |
|-------------------------|-----|

Necessary investments

The preliminary demand for the investments was determined in accordance with the prices of the analogical equipment sold in the markets of Lithuania and EU. More exact prices can be set while preparing the technical project or receiving commercial offers. The total price for main equipment of biogas plant and its construction is presented in the table below.

5.10 table. The price for the biogas plant construction at complex in Jonava district Municipality

| Name | Amount | Characteristics | Price, thous. Lt |
|---|--------|-----------------------|------------------|
| Waste tank with mixer | 1 | 500m ³ | 80,0 |
| Crusher and autoclave for animal waste | 1 | 10 t/d | 900,0 |
| Biogas reactors with mixers | 3 | 1000 | 3x600,0 |
| Biogas storage | 1 | 600 m ³ | 180,0 |
| Biogas filters | 1(3) | 300 m ³ /h | 3x105,0 |
| Separator of processed | 1 | 150 m ³ /d | 75,0 |
| CHP block with heat | 1 | 450 kW _d | 2500,0 |
| Technological process control equipment | 1 | - | 200 |
| Pumps station of waste processed and under processing | 1 | - | 155 |
| Total: | | | 6205 |

The preliminary price for biogas plant's construction - 6,2 million Lt. This price doesn't include the prices for buildings, land, ways and engineering nets.

5.3 The possibilities of processing the pig manure and other organic waste to biogas and its utilization for energy purposes at the complex in Si lute district

Place description, problems, current production of heat and electricity

The farm is located in Silute district Municipality. The heat is generated by two hot water boilers, capacity - 100 and 400 kW, firing wood and coal.

At the livestock farms of complex the calculated annual amount of the liquid manure amounts to approx. 80 thous. t of waste and annual amount of butchery waste amounts to 240 t of waste.

Potential of biogas based on calculations

After the analysis of the organic waste from livestock farms and butcheries it is assumed to extract 2,123 mln. m³ of biogas annually with 60 % of methane concentration and energy value -6.0 kWh. The preliminary calculations assumes that bio plant shall operate 8000 h per year.

5.11 table. The butcheries and stockbreeding complexes which can deliver organic waste.

| № | Name | Livestock manure amount, | Livestock waste, t./m. | Address | Phone |
|---|------|--------------------------|------------------------|---------|-------|
| | | | | | |

| | | | | |
|----------------------|-------|------|-----------------------------|---------------|
| UAB „Grabupeliai“ | 80000 | 240 | Grabupeliai, Silutes raj. | 84 4151651 |
| UAB „Vilke“ | ----- | 1083 | Silgaliu k., Silutes raj. | 84 4141145 |
| S.Budrio „Aisyte“ | ----- | 37 | Kebeliu k., Silutes raj. | 84 4144671 |
| UAB | | 670 | Smalkeviciu | 84 |
| R.Irmono „Rovisa“ | ----- | 2400 | Struiku k., Silales raj. | 84 4976144 |
| UAB | | 600 | Vingininku | 84 |
| UAB „Stragutes mesa“ | ----- | 200 | Stragutes k., Taurages raj. | 84 4661453 |

5.12 table. Biogas production potential of the analyzed complex in Silute district Municipality

| Waste characteristics | | Waste amount | Biogas production |
|-----------------------|-----|---------------|-----------------------------|
| Waste sort | S % | t / year | thous. m ³ /year |
| Butcheries' waste | 20 | 5230 | 523 |
| Live stock manure | 6 | 8000 | 1600 |
| Total : | - | 8'5230 | 2123 |

Calculations of the energy flows, security of energy supply reliability from the plant

The main technical and production indicators presented in the table below.

5.13 table . Energetic indexes of biogas CHP at the complex in Silute district Municipality

| | | |
|--------------------|----------------------------|--------------------------|
| Biogas production | Biogas production per year | 3.90 mln. m ³ |
| | Biogas production per day | 11820m ³ |
| | Calculated methane | 60% |
| Energy production | Electricity per year | 7.9 mln. kWh |
| | Heat per year | 1 1.46 mln. kWh |
| | Electricity per day | 23.9 tukst. kWh |
| | Heat per day | 34.7 thous. kWh |
| Energy equipments' | El. capacity | 1000 kW |
| | Heat capacity | 1450 kW |

The initial information of the complex lets to make conclusion that about 46 % of electricity and heat energy generated from biogas shall be consumed by farms and butcheries in possession of complex.

Necessary investments

The preliminary demand for the investments was determined in accordance with the prices of the analogical equipment sold in the markets of Lithuania and EU. More exact prices can be set while preparing the technical project or receiving commercial offers. The total price for main equipment of biogas plant and its construction is presented in the table below.

5.14 table . The price for the biogas plant construction at complex in Silute district Municipality

| | |
|--|------------|
| Total Investment expenses, Lt. : | 6810000,00 |
| Price of biogas reactor incl. mounting, Lt. : | 3310000 |
| Price for CHP incl. coolers and mounting, Lt : | 2340000 |
| Investments to CHP, Lt. : | 1160000 |

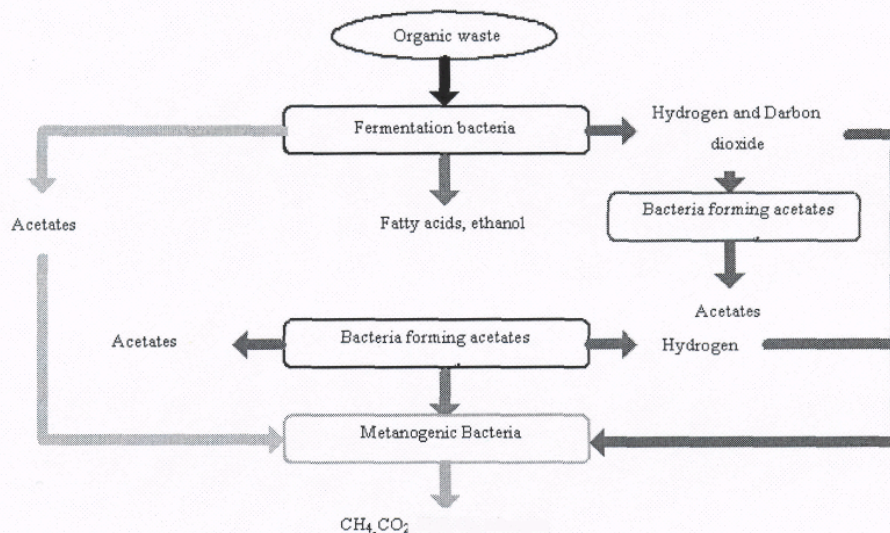
The preliminary price for biogas plant's construction - 6,8 million Lt. This price doesn't include the prices for buildings, land, ways and engineering nets.

6 Description of technologies (types of processes, issues of gas calorific value increase, biogas extraction technologies, selection of energy plant type)

During biogas production process the complex organic compounds are split to elementary ones which by means of methanogenesis bacteria is converted to biogas - methane, carbon dioxide and other gas compounds. [20, 21]. The conversion of organic substance to the biogas due to anaerobic bacteria proceeds in three stages: hydrolysis, fermentation and methanogenesis. Hydrolysis is a chemical reaction in which bacteria splits the complex compounds to trivial molecule ones - sugar, amino and fatty acids, which by fermentation are converted to ethanol, water, carbon dioxide and acetates. In the stage of methanogenesis the bacteria which release methane can use hydrogen, carbon dioxide and acetate as substrate to obtain methane in the process of metabolism. About 70 % of methane is produced from acetate and 30% from hydrogen and carbon dioxide.

6.1 picture. Biogas production process

Methanogenic bacteria are very sensitive anaerobics, therefore if the concentration of oxygen or nitrogen (ammonia) increase, its activity as well as emission of biogas, shall be restricted. The temperature, acidity and alkalinity, oxidation revivification potential and other



environmental factors must conform to its requirements. The activity of metabolism and intensity of methane production depends on following factors: composition of processed substrate, maintained temperature and its fluctuation, acidity, inhibitory factors.

The raw material for the biogas production is evaluated according the amount of biogas (m³) from the unit of the organic substrate mass and biomass mass. The industrial waste, containing much fat and protein, considerably increase the efficiency of the biogas plant's operation. However the usage of such waste is complicated due to over-dosage of fat and protein. The excess of fat increases the acidity of the substrate, and the excess of protein increases the nitrogen compound in substrate and amount of sulphuretted hydrogen in biogas. The biogas production process is inhibited in the both cases. These problems could be avoided permanently analyzing the composition of the processed waste and thoroughly dosing them.

For each particular sort of methanogenic and other microorganisms which participate in

the process is typical optimal temperature. In the biogas energetics it is assumed to divide the process temperatures into three groups: : psychrophilic (10-25 °C), mesophilic (25 - 40 °C), thermophilic (50 - 65 °C). In the psychrophilic environment the decomposition of the biomass and its conversion to biogas proceeds slowly - up to 100 days. It is recommended that the rapidity of temperature variation should be not higher than ± 2 °C/h - in psychrophilic, ± 1 °C/h - in mesophilic and $\pm 0,5$ °C/h - thermophilic regimes. The biogas is most intensive generated in the thermophilic environment. Comparing with mesophilic regime, the biomass processing period becomes shorter for 1,5 times, however the amount of biogas produced from the processed biomass approximately is the same, and the consumed energy for the heating of the bioreactor is 1,5 times more.

The microbiological activity in the biogas reactors is most favorable when the environment is neutral or low alkaline ($6,5 < \text{pH} < 8,5$). The substrates acidity in the bioreactor may be reduced by stopping or reducing the supply of fresh biomass.

The protein processed in the anaerobic way emit the nitrogen compounds. The concentration of nitrogen in the substrate is regulated by the proportion of carbon and nitrogen C:N in the raw material. The biogas reactor operates very well when this proportion vary in the limits of 13:1 -28:1.

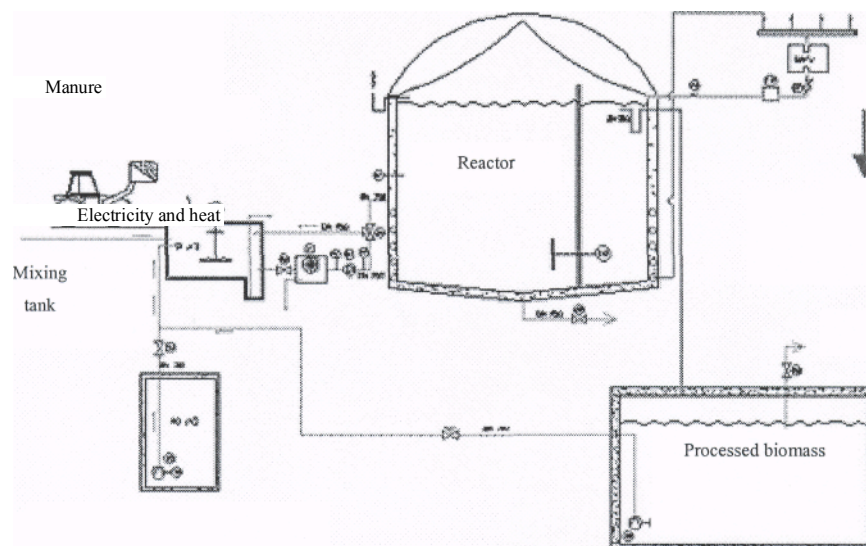
Thermophilic bioreactors are attractive on that score that the waste there is processed faster, the amount of biogas per day is bigger, and the dangerous microorganisms are treated. Thermophilic process usually is applied at the biogas plants, processing sewage sludge and waste of food industry.

Mesophilic bioreactors are widely used at the farmer's farms, where the animal manure, plants biomass and waste from the agricultural products are used as raw material.

At the classic biogas plant there is mounted the equipment for gathering, preparation and

Other waste

transportation of the raw material, bioreactors, storages for the produced biogas, treatment and burning equipment, tanks for processed biomass, separators, controllers of the technological equipment and data collectors, electricity and heat energy nets and equipment for distribution.



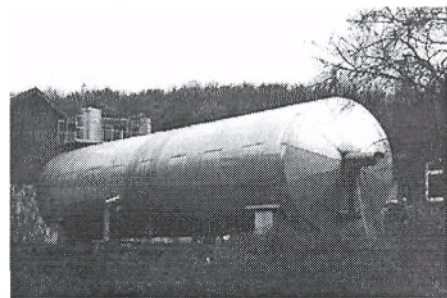
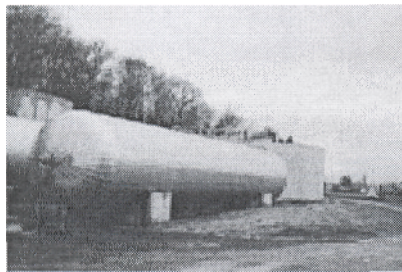
Reactor's heating

CHP

Dung

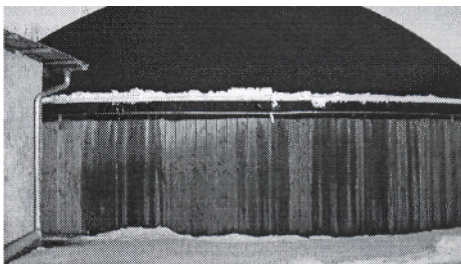
6.2 picture. *Principal scheme of the biogas plant*

The frame of the biogas reactor may be of different shapes - cylinder, sphere, rectangular parallelepiped. The selection of the shape and constructional material depend on the size of the reactor and parameters of the process. Currently in Europe there are popular reactors of cylinder shape which can be mounted horizontally or vertically. The horizontal reactor is made from the cylinder, welded from the structural steel, in the horizontal position. Spiroid located mixer is mounted in its center, and it is rotated by the motors mounted on the both ends. Usually the mixer is rotated in low speed (1-2 rev/min.). Such mixers are very efficient - substrate is well mixed and it use a little of energy. In such reactors it is easy to process the dense waste, which contain the additives of the inorganic nature and which are not difficult to remove through the special holes as they are sunken on the bottom of the cylinder. Such type bioreactors are prevailing at the biogas plants in farmers' farms.



6.3 picture. *Horizontal biogas reactors*

The main technological elements of vertical, cylinder shaped reactors are analogical as in horizontal reactors. However there can be adjusted the wider variety of the technological solutions. This type of reactors is able to maintain both mesophilic and thermophilic environment.



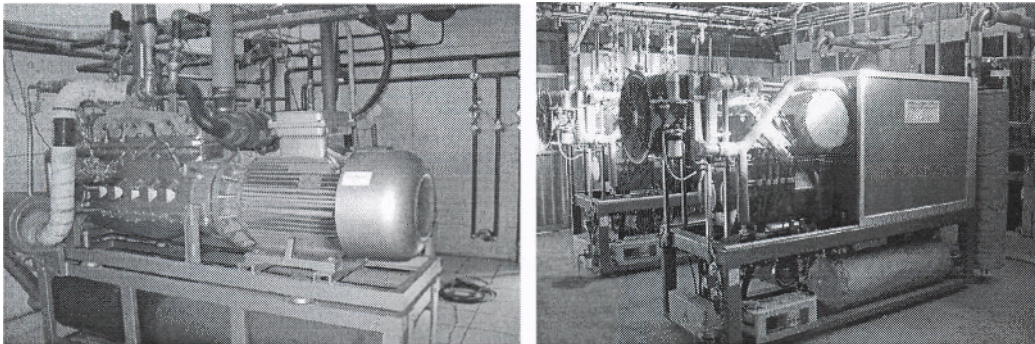
6.4picture. *Vertical biogas reactors*

For the processing of the concentrated waste from the industrial enterprises and settlements there are used one time or continual load, dense mass bioreactors, which process the biomass in which the concentration of dry substance amounts to 25 - 35%. The construction and production process of mentioned bioreactors are more complicated and price higher than for liquid load reactors. However they are popular for the processing of high concentration organic waste in the places with ecological sensitive environment. Their construction is similar to horizontal reactors, however the substrate load elements and mixers are installed differently.

The firing of the biogas in the gas boilers is the simplest way of energy conversion. In this case it is possible to use the common gas boilers for natural gas firing. Their burners must be adjusted due the different biogas and natural gas calorific value.

The heat generation at the biogas plants is profitable only if the heat energy is constantly consumed, because the surplus of heat or produced biogas is loss-making for the biogas plant. The boilers can be used in maximum at the boiler plant when biogas plant is integrated to common heat energy production and distribution network. In this case the deviation of necessary heat energy is compensated by others heat energy sources.

More economical and reliable firing of the biogas is in the gas engines, which are driving the power generators [10]. Such aggregates (CHP) produce electricity and heat energy. There is used the asynchronical and synchronical power generators and gas Otto or diesel engines which use the mix of biogas and diesel (up to 10%). The heat energy is obtained from the engine cooling system.



6.5 picture. CHP, firing biogas

The electrical efficiency of CHP, depending on the plant's size, varies in the limits of 20-38%. The bigger capacity CHP has the higher electrical efficiency. The users of CHP strive to produce as much as it is possible the amount of electricity for own needs and for sale to the power nets. The heat energy is used to maintain the biogas production process (up to 20%) and to satisfy the heat energy needs. The surplus of the heat (especially in summer time) is removed by the fan coolers installed outside. In every concrete case the decision to install the system (CHP, hot water boiler) is determined by the necessary amount of the investments. The project's repay period significantly becomes shorter due to the additional income for sold electricity and heat energy. However often there is no possibility to connect to district heating network due to typical location of the complexes on the out of town territory.

7. The economical calculations of biogas plant's installation at the particular object

In this chapter we shall present the economical evaluation of biogas plant's installation expediency at the complex in the Vilnius district. The forecasted indexes of biogas production and energy production shall directly depend on the amounts of the main business - pig breeding.

It shall be analyzed three possible versions:

1. The project shall be implemented without subsidies;
2. The project shall be analyzed receiving subsidies from EU structural funds;
3. The project shall be implemented as Joint Implementation project - additional income after selling CO2 quota.

Performing the economical assessment of biogas plant construction the following economical efficiency indexes shall be estimated:

- project's NPV; - IRR. As well it shall be set the present and discounted return times.

Usually it is assumed that the best version is when NPV and IRR are the highest rates and discounted return times - shortest.

Performing the economical assessment and taking into account the company's information and calculations presented in the chapter 5.1 the following assumptions shall be accepted:

- The period of 10 years shall be analyzed;
- Annual exploitation of CHP - 97 %;
- Biogas in the balance of the fuel - 100 %;
- The annual production of the biogas of the complex, assessing the coefficient of biogas

extraction store, amounts to 518500 nm³/year or in average 62,62 nm³ /h; - Biogas energetic value, assessing foreseen amount of methane - 6,0 kWh/ m³ ; - The price for buyable CO₂ equivalent - 7 €; - Income for utilized waste from butcheries - 380 Lt/t; - Plant's exploitation expenses - 5 ct/kWh; - Exploitation expenses of butcheries waste utilization - 35 Lt/t;

- The sold heat energy amount, taking into account the heat consumption in the previous years, amounts to 173,45 MWh/year; - Price for purchased electricity energy - 25 ct/kWh; - Price for purchased heat energy - 15 ct/kWh.

Taking into account the mentioned assumptions the summary of the expenses is presented in Annex.

The project's financial sources. Usually the small and average size enterprises have not enough capital for their expanding. The possibilities to borrow at the banks are too complicated therefore it is necessary to find additional financial sources. In order to improve the project's economical indicators there may be used different measures (borrower bank funds, loans on preferred conditions, own funds, or other possible financial sources. This Study analyses the alternative versions with different financial sources (loan, subsidy). The financial sources analyzed in the assessment of project's economical efficiency are presented below in the table:

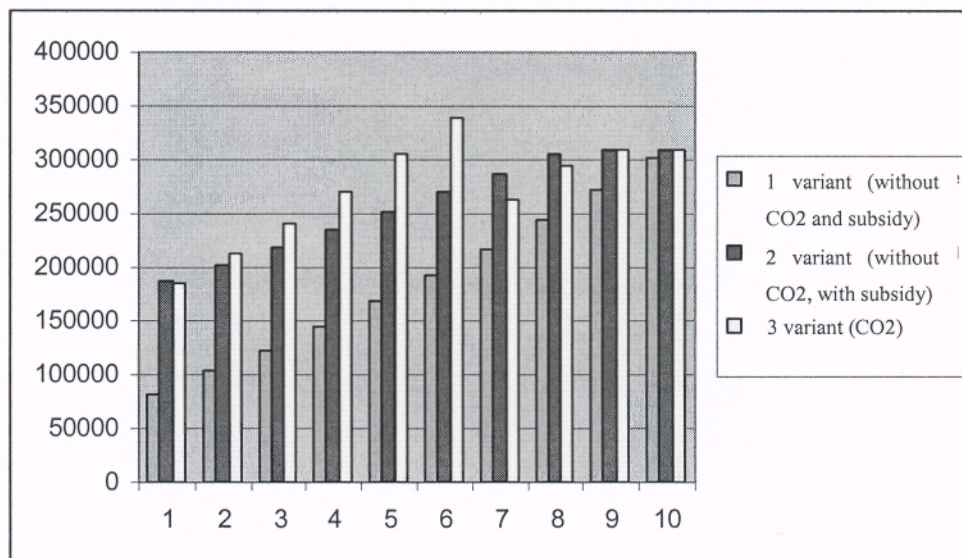
7.1 table . The possible project's development scenario are analyzed in the financial analysis.

| Assum | 1 scenario | 2 scenario | 3 scenario |
|-------|------------|------------|------------|
|-------|------------|------------|------------|

| | | | |
|------------------------|--|--|--|
| Income | - for utilized waste; - for electricity power; - for heat energy. | - for utilized waste; - for electricity power; - for heat energy. | - for utilized waste; - for electricity power; - for heat energy; - for CO2 |
| Project s financing | Loan - 3 880 000 Lt; period - 10 years. | Loan - 2 134 000 Lt; Subsidy - 1 746 000 Lt; Period - 8 year; period of subsidy' s expiry-10 years | Loan -3880000 Lt; Period - 8 years. |
| Other | Assumptions are same for all scenario; The return of loan only from the project's cash flows | | |

In the Chapter 5.1 there is presented preliminary price of the biogas plant's construction, not including price for buildings, ways and engineering nets, which amounts to 3,0 million Lt. The total demand for the investments is presented in the table - 3,88 million Lt.

The average annual rate of interest - 6% was used in the calculations. Following the calculations the received net profit according each scenario within analyzed period is presented in the table below.



7.1 picture. Net profit according each scenario

The project's profitability has been assessed by the methods of NPV and ERR. IRR was calculated not for the total enterprise's activity, but only for the planned to implement enterprise project's activity. The project's profitability indexes IRR and NPV and project's financial repayment period (simple and discounted) according each scenario assessing the cash flow from production investment and financial activities are as follows:

7.2 table. Project's profitability indexes

| Indexes | Scenario | | |
|----------------------|----------|-----|----|
| | 1 | 2 | 3 |
| NPV | 123 | 14 | 7 |
| IRR | 3.4 | 11. | 7. |
| Repayment period | 9.5 | 7.3 | 7. |
| Discounted repayment | 0 | 7.9 | 9. |
| PI | 0.8 | 1.2 | 1. |

The analysis shows that NPV is positive according all scenario. IRR in scenario 2 and 3 is bigger than annual rate of interest used in calculations. The project is unprofitable and unrepayable without subsidy and additional income, trading the gas which causes the greenhouse effect. Comparing the indexes of possible scenario we can see that scenario 2 or 3 should be accepted regarding possible investment. The selection should be stipulated either by possibility to receive the additional income from CO₂ trade (3 scenario) or using financing (2 scenario) to reduce the necessary amount of investment.

8. Summary, expanding the presented material to the plan of biogas usage for energy purposes in Lithuania

1. In the White Book of EU there is set the objective to increase the share of the renewable energy from 6 % to 12 % over total energy demand in EU by 2010.

2. Directive 2001/77/EC of the European Parliament and of the Council promotes electricity production from renewable energy sources and sets that by 2010 the renewable electricity amount at 15 EU countries must achieve 22%. The amount set for Lithuania - 7 % (presently 1,1%).

3. Implementing the program on the promotion of biofuel production and usage in 2004 – 2010 it is strived to produce 114 GWh of energy at biogas plants in 2010, including approx. 44 GWh of electricity energy.

4. Striving to reduce the environmental pollution with degrading waste and increase its usage efficiency for energy needs it is necessary to strive to process all biologically degrading waste to biogas. The assumptions are reasonable enough to produce energy 3-4 times more than foreseen in program.

5. The electricity energy from the biogas plants is purchased by 0,20 Lt/kWh tariff. However the Lithuania has no the consequent biogas energy development program and its promotion mechanisms which have other European countries. The financial promotion is necessary for the economical viability of such type projects. Appealing to the economical assessment of the typical stockbreeding complex without financial promotion and/ or additional income by trading gas which causes the greenhouse effect it can be concluded that the project is unprofitable and unrepayable.

6. There are 6 biogas plants in Lithuania. Currently 4 of them are in operation. The biogas plants can be constructed at the largest pig breeding complexes, water treatment enterprises, food waste processing enterprises.

7. The total capacity of the bioreactors installed at Lithuanian biogas plants amounts to 16 thous. m³. All plants are able to process about 350 thous. t/year of organic waste. The total energetic capacity of biogas plants amounts to 15.5 MW.

8. The experience of the operating biogas plants have shown, that the constructions of the different biogas reactors are suitable for the Lithuanian weather conditions. It is purposeful at the biogas plants use CHP for heat and energy production.

9. Lithuania has no traditions and experience to utilize the processed at the bioplants waste. The special technologies and equipment is necessary for waste watering. These technologies and equipment must be foreseen while preparing the new biogas plants projects.

10. Lithuania has good possibilities by using the uncultivated lands to grow the energy plants and utilize for the biogas production.

11. It is necessary to built more demonstrational biogas plants striving to more rapid spread of the technologies. The Lithuanian designers, constructors and the industrial enterprises could be able to create biogas plants' technological equipment, which presently is in great request in the European market.

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