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FARM-SCALE BIOGAS PRODUCTION POSSIBILITIES IN LENINGRAD REGION

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CONTENTS

INTRODUCTION

The choice of the topic and the thesis relevance are determined by the need of study of possible scenarios, management tools and cost effectiveness analysis for biogas station implementation.

The aim of the thesis is to analyze key parameters of the anaerobic digestion process, introduce applicable management tools and evaluate the cost-effectiveness of biogas station project in the Leningrad region. The raw materials for biogas are waste from agriculture, cattle and chicken farms.

Agricultural sector is one of the most significant spheres in national economy. Waste produced from farms is a good source for biogas production. Anaerobic digestion is an environmental technology process, which enhances material and energy efficiency via utilizing organic material streams as energy. Besides energy production it can be utilized for producing of fertilizers and be a good alternative (or best available technology) for the waste management.

Increasing energy and fertilizer prices with the decreasing oil and nutrient resources caused the interest in biogas projects either on farm-scale or as cooperatives involving several farms. However, biogas production has to be economically beneficial. The main incomes can be received by biogas plant from gate fees, energy production, production of fertilizers, environmental payments reduction. For better cost-effectiveness different parameters and scenarios have to be analyzed.

To achieve the goal the following issues should be investigated:

- Review the agricultural sector in Russia and its potential from the point of biogas production.
- Study Russian legislative considering energy production from renewable energy sources, fertilizer usage.
- Study anaerobic digestion, i.e. biogas technology, and identify parameters and tools for better project management.
- Using economic scenario tool developed by the Mikkeli University of Applied Sciences, evaluate cost effectiveness based on different indicative parameters.
- Provide technical and ecological analysis for the suggested project.
- Give recommendations on improving biogas station profitability.

The object of the research is the agricultural enterprise JSC «Partizan» on the basis of the Luga-Balt project. Luga-Balt project is a long-term project of South-East Finland – Russia ENPI CBC, aimed to support cross-border cooperation across the border between the participating regions of Finland and Russia. The aim of the project is to create conditions for the eliminating emissions of biogenic elements from the rural areas to the Luga river, using the experience of Finnish environmental organizations. The project complies the Baltic Sea Foundation 2020, the main purpose of which is a reduction of the Baltic Sea eutrophication (Foged, Henning Lyngso, 2010, 2). To achieve this goal it is supposed to reduce leaching of nutrients from active livestock farms in the Baltic Sea by the technological development and the dissemination of information on best available techniques. Biogas production is a great breakthrough in the field of technological development and could be the best available techniques as it solves waste management issue and provides heat and electricity.

The study feasibility is in the economic project evaluation based on indicative parameters, that is provided with an economic scenario tool, developed by Mikkeli University of Applied Sciences. It is used to examine the cost-effectiveness of the farm-scale biogas plants in South-Savo region in Finland. The indicative model takes into consideration the following aspects:

- Availability of material
- Type of the energy production plant (heat and/or heat and electricity) with its technical characteristics
- Plant’s heat and electricity consumption
- Investment costs
- Financial support
- Operational costs
- Energy prices
- Gate fees

1. ANAEROBIC DIGESTION AND BIOGAS PRODUCTION

Anaerobic technology is a microbiological process in which microorganisms break down organic matter, in the absence of oxygen, into biogas (a mixture of carbon dioxide (CO2) and methane) and digestate (a nitrogen-rich fertilizer) (The Parliamentary Office of Science and Technology, 1).

Biogas production has several benefits, including (Balasubramaniyam U., 11):

- energy production – heat, electricity or vehicle fuel;
- environmental emissions minimization – less CO_2, NO;
- controlled stabilization of organic material;
- production of high quality organic fertilizers;
- micro-economical benefits through energy and fertilizer substitution, additional income;
- sources and increasing yields of animal husbandry and agriculture**.**

The decomposition of biowaste occurs in four stages: hydrolysis, acidogenesis, acetogenesis and methanogenesis (United Tech 2003, 18). During the first stage, hydrolysis, bacteria transforms the particulate organic substrate into liquefied monomers and polymers, i.e. proteins, carbohydrates and fats are transformed into amino acids, monosaccharides and fatty acids respectively. In the second stage, acidogenic bacteria transforms the products of the first step into short chain volatile acids, ketones, alcohols, hydrogen and carbon dioxide (Ostrem 2004, 6-9). The common products from acidogenesis stage are propionic acid (CH_3CH_2COOH), butyric acid ($CH_3CH_2CH_2COOH$), acetic acid (CH_3COOH), formic acid (HCOOH), lactic acid ($C_3H_6O_3$), ethanol (C_2H_5OH) and methanol (CH_3OH). In the next stage, acetogenesis, some of the acidogenesis products, i.e. the propionic acid, butyric acid and alcohols are transformed by acetogenic bacteria into hydrogen, carbon dioxide and acetic acid and then are utilized by the methanogenic bacteria in the final stage, methanogenesis. During this stage, microorganisms convert the hydrogen and acetic acid formed by the acid formers to methane gas and carbon dioxide (Verma 2002, 28-30).

Anaerobic digestion process can be classified in dry (Total solids (TS) > 20 %) and wet (TS <15 %) digestion.

Wet digestion is characterized with (Bioste Oy)**:**

- Content of total solids is less than 15 %, can be pumped to the reactor
- Digestate total solids content is less than 8 %

Wet digestion is used for liquid raw materials, such as liquid manure, sludge and industrial wastewaters that contain small content (2-6%) of total solids.

Even though the digestate contains a lot of nitrogen and can be utilized as a fertilizer, but in many countries liquid composition is not allowed to be used. In Finland, for example, it is considered as a wastewater that must be treated in a wastewater treatment plant. Phosphorous must be destroyed and most of the nitrogen must be lead directly to the water works because wastewater treatment plants are not able to remove it. The digestate can be separated into two phases after which solid phase can be used as fertilizer and the liquid, or reject water, can be lead to the wastewater treatment plant (Bioste Oy).

Nowadays wet digestion is the most common anaerobic digestion process. The reactors are reliable, simply structured and are most often in continual operation. Thus, degradation and biogas production are stable.

Dry digestion is characterized with (Bioste Oy):

- Feed total solids (TS) content 20–50 %
- Digestate total solids content 5–20 %

In dry digestion process feed materials are solid, so the reactor contains less water than in case of wet digestion. That’s why a smaller reactor is required.

Dry digestion is less popular than wet one. There could be problems with mixing and it causes unstable process of biogas production.

There are different materials, which can be utilized as a feedstock for generating biogas in anaerobic digesters. As agricultural feedstock is regarded (Smith, P., 499):

- Animal manure
- Energy crops
- Crop residues
- Algal biomass

A livestock manure usually is regarded as a lower-energy feedstock because it is predigested in the gastrointestinal tracts of the animals (The Biogas Site, 2012). But manure is a good choice for anaerobic digestion because it generally has a neutral pH and a high buffering capacity (the ability to resist changes in pH); it also contains naturally microbes, which proceed anaerobic degradation; provides an array of nutrients, micronutrients, and trace metals; is available in large quantities; and, finally, can be pumped into the reactor.

The biogas potential of different feedstock depends on the source, pretreatment, volatile solids (VS) concentration, chemical oxygen demand, moisture content, and inclusion of toxic compounds. Biogas primarily is a mixture of methane (CH_4) and carbon dioxide (CO_2). Different sources of substrate lead to different specific compositions. According to Rainer János, the composition of biogas from agriculture, (2012, 65-75) is shown in the Table 1 (János R, 2012, 65-75):

TABLE 1. The composition of biogas from agriculture:

Compounds	
Methane, %V/V	60-70
Carbon dioxide, %V/V	30-40
Nitrogen, %V/V	<1
Hydrogen sulfide, mg/m3	<600
Ammonia, mg/m3	<100
Siloxanes, mg/m3	0-50
Oxygen, % V/V	0-1

1.1.1 Optimization of the biogas process

Different biogas farms can focus on different goals. For some plants, the main goal is to produce biogas energy, the other one specialize more in waste treatment. To achieve better performance, i.e. higher methane yield, stable process, good reusable end products, biogas process has to be optimized. Besides technical benefits, optimized process has better prerequisites to be economically feasible.

There are some process parameters that affect the result of the process. It can be:

- pH

The change in pH can be both an indicator and the reason of process imbalance, since the microorganisms can function only in a specific range of pH (Kanokwan 2006). The reason for pH insensitivity is the high buffer capacity in the material.

- Alkalinity or buffering capacity

Buffering capacity is a better alternative than pH for indicating VFA accumulation, since the increased VFA will directly consume alkalinity before large pH changes.

- Organic loading rate (OLR)
- Hydraulic retention time (HRT)
- Inhibitors presence (Volatile Fatty Acids (VFA), sulphur, nitrogen)

VFA also affect pH rate, making the process not stable. The VFA increase (especially when alkalinity decreases) leads to an acidification in the fermenter.

A co-digestion is a process where energy-rich organic waste materials (e.g. fats, oils, and grease (FOG)) are added into the biogas process to excess capacity (The Dutch Foundation for Applied Water Research).

A pretreatment of substrates can increase biogas production, increasing VS and substrates solubility as well. There are several pretreatment methods to enhance biogas production. It is not easy to identify the most suitable pretreatment for all types of materials. Different methods have different effect on different substrates with different mixing ratio of inoculum and substrates. The effective pretreatment has a function to increase the substrate porosity that makes the carbohydrates more accessible for enzymes and to preserve different fractions without losing or degrading organic matters and bound the formation of inhibitors. Every pretreatment has advantages and drawbacks. The optimal operation depends on the material loading into the reactor.

Depending on the biogas usage purpose different biogas treatment steps are necessary. For grid injection the gas has to be upgraded. The energy content of biogas is in direct proportion to the methane concentration and by removing carbon dioxide we can get higher energy content of the gas (Hanjie 2010, 2-18).

1.1 Cost-effectiveness of biogas production

A biogas production can bring significant economic benefits from generation of electricity and heat, and fertilizer production, as well as environmental payments reduction. The biogas projects reduce the amount of harmful emissions into the environment of greenhouse gases (methane and CO2). The payback time of a biogas project is about 3-7 years.

Social observations by the European Commission proved the fact that the growth of biogas energy can solve the problem of employment in rural areas and increase the population income (AEnergy.ru). Thus, the quality of life of the rural population is significantly improved.

Moreover, biogas helps to develop agricultural sector, increasing its compatibility. The share of imported products in the market is high and keeps on increasing. At the same time in the agriculture of the developed countries the output is 30% higher than the population demand for food, so the surplus goes to the Russian market. The measures to improve agriculture sector competitiveness have to be developed. Currently the prices of agricultural products are low and their growth rates are slower than the price of industrial products and services. Thus, the selling price of grain is about 35% of the world level; the prices of livestock do not reach even 40% of the world price. Livestock production cost does not allow domestic enterprises to compete at the global market. So, the biogas production can improve the profitability of agriculture with self-supplied energy and free high quality fertilizer (Ushachev 2009, 4-12).

Possible sources of income from biogas production:

Environmental payments reduction

A fee for waste disposal is regulated by the Government Resolution of 12 July 2003 № 344. The fee for the disposal of the waste of hazard class III (waste pig farms and poultry farms) is 12,1 €/ton, waste of IV hazard class (cattle waste) 6,1 €/ton.

Funding under the Kyoto Protocol

Financing of energy efficiency and energy conservation projects can be achieved within the framework of the Kyoto Protocol. "Kyoto Protocol" describes two instruments of international conventions: the UN Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. The countries that signed the Kyoto Protocol commit to reduce their greenhouse gases emissions. Emissions reduction made by the company can be "certified" by the government and sold on the international market quotas, or at a price agreed in advance with the investor, which is usually not very high, either at the market price at the time of sale.

Production of 1000 cubic meters of biogas provides replacement of 10 tons of CO_2 emissions. The average market price of 1 ton of CO2 is 10 Euro. Medium-sized biogas projects with capacity of 5 million cubic meters per year provide a revenue of 0.5 million euro.

Production of electricity and heat for own use (or gas)
1 cubic metre of biogas is equal 0,6 cubic metre of natural gas, 1,5 kg of firewood and 1 litre of diesel fuel. From 1 cubic metre of biogas we can produce 1,5-2,2 kWh of electricity, 2,8-4,1 kWh of heat.

Production and use of organic fertilizer.
From 1 cubic metre of biogas 4-4,5 kg of fertilizer can be produced, but there are some limitations: 1) Capital costs will be reflected in the cost of production; 2) The lack of interest in the third-party involvement in the project; 3) Legislative base is weak. To reach a low cost production it is important to be profitable through the sale of products, mainly heat and electricity. Key points to achieve low costs include:

1. Cheap substrates (payment for the treatment of substrates, i.e. gate fees) and steady availability;

2. Substrates with high output power, which gives high gas production;
3. Fertilizers usage in ecological cultivation;
4. Good investment policy;
5. Economic support;
6. Low cost of labour, services, analysis, etc.

Additionally by-product from biogas process is fertilizers are sold for 10 euro per ton.

1.2.1 Government support of the Russian Federation

The Federal Law № 250 "On Amendments to Certain Legislative Acts of the Russian Federation in due to the implementation of the reform measures of the Unified Energy System of Russia" sets the main financial mechanisms to support the production of energy from renewable energy sources. They include:

- mechanism of allowances to the wholesale market price of renewable energy;
- subsidizing the cost of connection to the network for generators with capacity ≤ 25 MW and ability to meet other expenditures of the federal budget;
- obligations of network organizations to purchase renewable energy;
- other measures to support energy production from renewable energy sources at the expense of the federal budget.

The Russian government does not subsidize renewable energy production compare to EU countries. It means that every biogas plant operator either needs to negotiate with the energy suppliers regarding the power supply into the local grid or to use the generated electricity itself.

In general engineers and businessmen are looking for the best and the cheapest fuel source that can produce a lot of energy and supply the community with electricity. The modern technologies discover possibilities to extract energy from solar energy, wind energy, biomass and etc. The current situation of biogas production in the EU markets is steadily improving, while the situation remains weak in Russia. One of the main reasons for low biogas production level is pricing policy. As long as there is a low price for fossil fuel and weak government support, biogas production remains unprofitable.

As a concrete example may serve the AEnergy's comparison for natural and biogas in the Europe and Russia per 1000 m3 (all costs are given in average to monetary exchange rate):

- European price for natural gas = 350 Euro (or even more)
- Russian price for natural gas = 100 Euro (or even less)
- European price for biogas = 200 Euro
- Russian cost for biogas = 180 Euro

And in turn, as an example for cost-effectiveness estimation Belorussian project "Construction of a biogas complex in Open Society "Baranovichkhleboprodukt" is introduced. The capacity of the biogas power complex is 0,9 MW and it produces electric and thermal energy and organic fertilizers as well. The raw material (cattle waste) is provided by pig-breeding complex and three dairy farms. The pig farm is large having 70 thousand pigs. Financial figures for the project are presented below.

The general investment expenses for the project are:

Total **2,97 million euro.**

Including capital expenses: **2.8 million euro**

Preliminary financial parameters of the project:

Proceeds without the VAT: **313 millions euro.**

Simple time of recovery of outlay: **5,6 years**

Dynamical time of recovery of outlay: **8,4 years**

Internal norm of profitableness: **12,3**

The pure discounted income: **224 millions euro.**

The rate of discounting: **16**

In Russia energy produced from biogas is mainly used for fertilizer production, but it is good as an alternative for waste reduction as well. The energy is utilized for own use – electricity and heat, as the energy price is low. Also there is a legislative boundary – lack of "green tariff". But still biogas production is becoming more and more important issue, because the natural gas price increases by 15-20 percent annually whereas 1 m3 of biogas costs around 0,1-0,15 € (Center of alternative energy).

Despite the lack of the Russian Federation "green tariff" for electricity generated from biomass, biogas Russian market can develop rapidly through projects aimed at recycling various kinds of agricultural waste. However, the adoption of "green tariff" will significantly speed up the formation of a new industry.

1.3. Current situation of bioenergy in Russia. Renewable energy potential

Russia has a huge potential of renewable energy sources: geothermal, solar, hydro, wind, and biomass. Nevertheless none of them are competitive because of low prices for fossil fuels, but they are competitive in environmental way of thinking. Despite the enormous amount of energy exports, many Russian regions have a lack of energy, and the use of renewable energy would be cost-effective for them. Renewable would be more used in Russia, if the government create better energy policy and utilize the experience from other countries..

It can be stated, that Russia has a remarkably large stocks of various sources of renewable energy due to its geographical location, size, diversity of climate and topography.

The potential of renewable energy resources is about 30% of total primary energy consumption in Russia. So far, the potential is practically unused. If you do not take into account the large-scale hydroelectric plants, the share of renewable energy in Russia is about 1% of the primary energy consumption of the country.

The main reason for the depression of renewable energy production is low domestic price for natural gas (Energy forum, 2009). However, since the gas price is expected to increase, the economic attractiveness of renewable energy should go up, too.

Accepted in 2003 the Russian Energy Strategy say that the possibility of economic use of renewable energy has improved recently due to the reduction of the development of technology use cost and the price of fossil fuels increase.

Recently changes that are taking place in the gas market are objective and powerful incentives encouraging the rapid development of renewable energy in Russia. According to the data of the General scheme of gas industry development the annual gas production volume will fall to 200 billion cubic meters in 2030, and create the need for the increased gas production. And, Russia has a significant capacity for agro-industrial complex. Annually about 624.5 million tons of organic waste are produced. Thus about 31 225 million m3 of biogas could be got from it, that is equal 68,695 GWh of power generation and 85 869 GW of heat (Research company Abercade Consulting, 2012).

Biogas production in Russia began in 2009, when the first biogas plant (with capacity 100 kW) was launched in the Kaluga region. In September 2011 the biogas plant (with capacity 2 MW) was put into operation in Kursk. The plant is designed to process 105 tons of pig manure and 105 tons of corn silage per day. Two large pig farms supply with raw materials. Farm size counts 60,000 heads and in the near future population will be increased to 80,000. Currently, the country has one big commercial biogas plant "Luchky" (with capacity 2.4 MW) in Belgorod region.

The present biogas production scale across the Russia is low. The capacity of the biogas plants which are already operating is weak and can cover only small areas of electricity demands. Currently biogas is not used as a fuel vehicles like in many European countries.

2 AGRICULTURE IN RUSSIA

Comparing with the Europe, farms in Russia are bigger with extensive territory and possibility to keep more cattle, pigs, chicken etc. According to the Official representative office of the Kolomna municipal district, the average farm area is 3.0-4.0 thousand ha with a livestock about 1000 heads.

In many developed and developing countries the share of agriculture in the GDP is a big part. In Russia, the relative share of agriculture is increasing every year, but still remaining low. The share of agriculture in the national GDP was 8% in 2011. In 2009-2010 this figure was 5.49% and 5.55% respectively. The number of crop producing areas increased from the year 2007 to 2009, but in 2010 the growth stopped. The land reduction in 2010 was 2.6 million hectares compared to 2009 (Research company ID-Marketing). That was due to spring and winter wheat harvest decline in Russia.

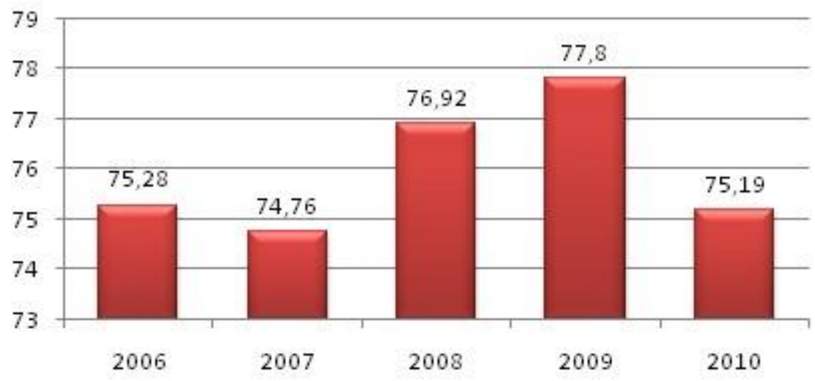

FIGURE 1. The dynamics of crop area in 2006-2010, mln. Hectares

In 2011 the grain harvest has grown significantly and was 92 million tons (according to the Ministry of Agriculture). The growth rate was 48% compared to the year 2010. Agriculture is a major supplier of raw materials for the food, feed, light and other industries. Agriculture in Leningrad region is specialized mainly in dairy cattle, potatoes, and poultry. It includes 540 large and medium-sized enterprises, including 264 agricultural enterprises, 6 feed mills, 123 - the food processing industry, 147 - fishing industry enterprises.

Russia has a considerable biogas production potential that is not utilized yet. The total market potential for biogas is more than 18.4 billion USD. At the same time, the production of biogas produced in agriculture could reach 14.7 billion cubic meters per year that is equivalent to 10 billion cubic meters of natural gas. Main resource for the development of biogas industry is animal excrements (153 million tons per year). It should be noticed, that with the good planning and logistic amount of biogas produced in farms could be increased notably, when suitable organic fractions from municipalities and industry are co-digested (Research company Abercade Consulting, 2012).

2.1 Investments in Farming in the Leningrad region

Over the last 6 years 0.95 billion € have been invested in the agriculture of Leningrad region, including 0.2 billion € in 2011. The volume index of capital investments for the 9 months of 2011 was 108.5% (Agriculture and fisheries complex in Leningrad region 2012, 5-7).

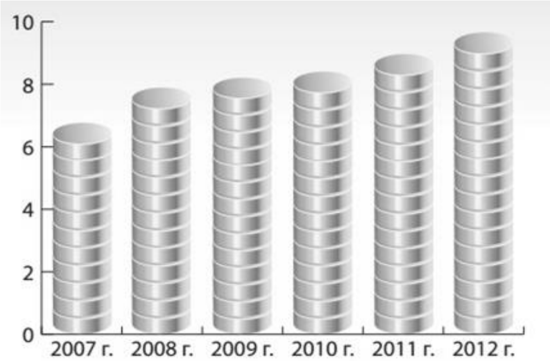

FIGURE 2. Investment in capital assets

State support for the Leningrad region agriculture within the bounds of "rural social development" program (million Euro).

TABLE 2. State support (million Euro) for the Leningrad region agriculture.

	2007	2008	2009	2010	2011	2012
Federal budget	11	29.3	41.5	36.6	53.65	51.2
Leningrad region budget	21.5	39	43.9	46.3	48.8	58.5
Municipal district budgets	0.7	0.97	1.46	1.22	1.95	2.2
TOTAL	33.2	69.27	86.6	84.2	104.4	111.9

2.2 Agriculture and biogas production

Despite the enormous potential of bioenergy sector in Russia, the total energy production is very low, about 1%. The equal percentage in the Europe is more than 13.5% of the total energy production (Shkradyuk 2010, 24).

Low rates of electricity production from renewable energy sources are results of (Russian Energy Strategy 2009, 74-76):

- Lack of competitiveness of projects using renewable energy sources compared to solutions based on the use of fossil organic fuel;
- Institutional barriers related to the lack of regulatory methods that encourage the use of renewable energy in the electricity sector;
- The lack of federal and regional programs to support large-scale use of renewable energy sources;

- Lack of technical and procedural documentation, software tools needed for design, construction and operation of generation facilities, operating on the basis of renewable energy sources,

- Lack of public resources to support the development of electric power from renewable energy sources.

In Russia there are 10 biogas plants, but they are focused on own needs and don't sell the energy to the grid. The interest in biogas plants increased since launching of the biogas staton "Luchky" in March 2012. This is the first Russian commercial biogas station with capacity 2.4 MW. Every year it produces 19.6 million kWh of electricity and 211.67 MW of thermal energy (daily electricity production is about 56 thousand kWh) and 66,800 tons of organic bio-fertilizer as well (Table 3) (Belgorod Institute of alternative energy, 2013).

TABLE 3. Technical-economic indicators, "Luchky" biogas station

Capacity:	2.4 MW of electricity
Electricity generation:	19.6 million kWh /year
Heat production:	18.2 thousand Gkal/ year
Processing (per year):	• 14,6 thousand tons of massacre waste • 26,000 tons of pig waste • 1,8 thousand tons of sewage sludge as a: • 26 tons of silage • 5 tons of water In total 73,400 tons per year.

2.2.1 Renewable Fertilizer

Fertilizers can be divided into organic fertilizers (composed organic plant or animal matter) and inorganic fertilizers. Both organic and inorganic fertilizers provide the same chemical compounds needed for the plants. Synthetic fertilizers are used for growing all crops (Parnes 1986, 14-19). Fertilizers can be a reason of soil imbalance if the leaching occurs. Stability of the system is reduced by the extensive use of nitrogen-containing fertilizers that cause soil acidification.

Organic fertilizers include natural organic materials, (e.g. compost, manure, chicken litter). Poultry litter and cattle manure often cause environmental and disposal problems, making their use as fertilizer beneficial (Bolan 2010, 676-681).

Animal farms and complexes are the most dangerous objects in agricultural sector. They affect the environment with animal waste. Hazardous level depends on the waste kind, dilution rate, leaching.

There are some ways of manure treatment and utilization.

1) Manure composting. Materials are used: solid manure (humidity 65-70%), liquid manure (humidity 90-92%) and a solid fraction (humidity up to 75%) after the separation of manure (Peregudov 2012).
2) The most advanced technology for the manure treatment and is the separation of solid and liquid manure fractions. It has benefits, such as:
   • significant cost savings on the lagoon construction level (the volume is decreased by 1.5-2 times);
   • lagoons are easily mixed, not silted and serve a long time;
   • odor intensity reduction (the sanitary protection zone can be reduced by 2 times);
   • operating cost saving (up to 3-5 times) (Peregudov 2012).
3) Also there are biological methods of manure treatment that can be divided into natural and artificial. Natural methods are based on the biochemical destruction and mineralization of organic matter by microorganisms occurring in natural conditions - in sedimentation tanks, ponds, lagoons, soil and compost. Artificial methods are based on the biological processes in artificially created conditions - in the digesters (IzhAgroMash 2012).

According to Iowa State University, 2012, the agriculture sector inputs significant share of greenhouse gases into the atmosphere (8.2%). The main sources are soil and manure management (Table 4) (Iowa State University 2012).

TABLE 4. U.S. Agricultural Greenhouse Gas Emissions by source

Source	Percent of agricultural emissions
Agricultural soil management	61
Enteric fermentation	18
Manure management	9
Fossil fuel consumption	7
Other	4

Manure is still widely used as fertilizer at the agricultural farms, but it still remains is considered as a problem at the animal farms due to legal limitations. The current situation might be accentuated if the government introduces a tax for manure usage as it was accepted in Kazakhstan (BBC 2012. Kazakhstan manure tax).

Prerequisites for biogas industry development are evident. Despite the domestic policy for the prices that have been established by one of the largest agricultural companies, JSC "Uralkali" (the price for domestic consumers should be set no more than the minimum export price); the price for mineral fertilizers has increased by 50% (Finam analytics, 2012). Prices for natural gas and electricity are increasing as well. The indexes of the price increases are shown in the Table 5 (The Russian Association of Fertilizer, 2010).

TABLE 5. Growth rates of prices and the index of industrial prices in Russia, %

Indexes	**2008**	**2009**	**2010**
Growth index price of natural gas	128,3	121,5	115,0
Growth index price of electricity	118,54	113,46	107,6
The index of industrial prices in Russia	93,00	113,90	110,0

2.2.2 Greenhouse gas emissions from agriculture

Agriculture, particularly cattle, is one of the main greenhouse gases sources. The UN report (2006, 8) noted that cattle produce more greenhouse gases than cars. In livestock greenhouse gases (mostly methane) are formed in the intestinal fermentation and animal manure decomposition. The main sources of greenhouse gas emissions in agriculture are land application of organic and mineral fertilizers, organic fixed nitrogen, wastewater from fields and crop residues, greenhouses, cultivation of drained land. This releases N_2O, CO_2, CH_4 (Grenkov 2008, 15-17).

Agricultural activities contribute to emissions in different ways (Grenkov 2008, 15-17):

- Different management practices for agricultural soils (from fertilizer application to methods of irrigation and tillage) can lead to production and emission of nitrous oxide (N_2O).
- Livestock, especially cattle, produce methane (CH_4) as a part of their digestion. This process is called enteric fermentation and represents one third of the emissions from the agriculture sector.
- The way in which manure from livestock is managed also contributes to CH_4 and N_2O emissions. Manure storage methods and the amount of exposure to oxygen and moisture can affect how these greenhouse gases are produced.
- Smaller sources of emissions include rice cultivation, which produces CH_4, and burning crop residues, which produce CH_4 and N_2O.

The most significant sources in the agricultural sector include direct N_2O emissions from agricultural soils, and CH_4 emissions from enteric fermentation pets. By 2008 N_2O emissions from agriculture decreased by 45.0%, and CH4 emissions from enteric fermentation processes decreased by 59.5% (Grenkov 2008). Emissions reduction is associated with a decrease in livestock and poultry population, reduced acreage and amounts of mineral nitrogen fertilizer due to the economic reforms in the agricultural sector. Despite the N_2O and CH_4 emissions decrease, the total greenhouse gas emissions increased by 13.0% in 2008 compared to 1998.

3.0 LEGISLATION

The present study work is aimed to analyze the system of implementing biogas station, considering legal requirements, and find the threats and possibilities to avoid uncertainties and reach the cost-beneficial biogas production.

3.1 Development of green-legislation in Russia

Among the major difficulties of the bioenergy development in Russia there is a lack of state support, low prices for electricity and heat, problems with investment, bureaucratic difficulties with the coordination of projects, etc. The constant material availability is compulsory circumstance for biogas plants profitability.

The first steps of the Russian government towards the development of renewable energy sources were made on November 4, 2007. The updated Federal Law N35 «On Electric Power Industry" introduces the concept of renewable energy sources and defines renewable sources, the basic directions, principles and methods considering renewable energy production, such as:

1. Giving out permits confirming a certain amount of generation from renewable sources
2. Establishment of markup to the equilibrium price of the wholesale market for generators based on renewable energy
3. Establishment of mandatory volume consumption of electricity produced from renewable energy sources.
4. There are many issues related to the legislation in the field of alternative energy.

The Federal Law № 35-FZ "On Power" prescribes the general rules applicable to the implementation of the power industry, but the question of tariffs for renewable energy (i.e. the retail electricity market) remains open due to the lack of federal methodology for calculating a "green the tariff". Currently the "Regional Centre for Biotechnology" cooperates with FSUE "Russian Energy Agency," the Ministry of Agriculture and the Ministry of Energy on all open issues in implementing similar projects (Energosvet).

Two documents were approved for the purposes of the legal framework. The first one is a provision of Government of the Russian Federation № 426 from June 3, 2008 "On the qualification of the generating facility from renewable energy sources", which defines the generating facilities eligible for state support. This could be a generator that meets the following criteria:

1. Functioning based on renewable or on a combination of renewable and other energy sources
2. Connection to the grid network and the necessary means of measurement
3. Meeting targets.

Another document - Order № 187 of the Ministry of Energy on November 17, 2008 «On the order of the registry issue and redemption of certificates confirming the production of electric power generating facilities for skilled, functioning on the basis of renewable energy sources"- establishes a system of registration and compensation of certificates confirming the generation from renewable sources and sets certificates for the different sources of energy. Validity of the certificates is set for 3 years.

One of the most important documents was approved on January 8, 2009 - Government Order N1-p "The main directions of the state policy in the field of energy efficiency of electric power from renewable energy sources by 2020". It establishes the principle of public policy, a set of measures for the development and targets, such as 4.5% of electricity from renewable energy sources to the total energy generated in 2020.

Thus, the government has approved some legislative documents on renewable energy production, but some points, such as kind of certificate, markups, green-tariff and sources of funding, are still unclear.

3.2 State policy of the Russian Federation

State policy on energy efficiency of electric power from renewable energy sources is an integral part of the energy policy of the Russian Federation.

According to the Russian Energy Strategy in the period up to 2030 (2009, 4-8): “Energy, based on renewable energy sources, will be developed, including hydropower, solar power, geothermal power plants and district heating plants, bioenergy and wind power plants, waste incineration and waste-energy complexes in major cities.”

For the period up to 2020 the target level of production and consumption of electricity from renewable energy sources will adjust:
in 2015 - by 2.5 percent;
in 2020 – by 4.5 percent.

At the moment, the Ministry of Energy is developing a draft decree "On changes of some acts of the Russian Federation on promoting the use of renewable energy in electric power and energy." The main aim is to support renewable energy through market power, as well as reducing the level of bureaucratic regulation of the sector.

In addition, in April, the government approved a comprehensive program of development of biotechnology in Russia up to 2020, where bioenergy is one of the significant targets. For its support 367 billion rubles will be allocated. The document refers to the establishment of technological and technical basis for the development of bioenergy, support engineering and manufacturing equipment, as well as support for regional projects in the field of power and heat from biofuels.

According to the Order of Ministry of economic development “On approval of the indicative list of activities in the field of energy-saving and energy efficiency that can be used in the development of regional and municipal programs for energy-saving and energy efficiency” among the activities on increase of the usage of energy there is an activity that assumes the use of biomass, waste wood and agricultural, municipal waste, methane, biogas for electricity and heat production.

To conclude, the Russian Federation current policy has started developing by means of different programs that are aimed to increase the share of biotechnology in the field, including biogas production, but the system is quite weak and needs to be improved. There is a need for an adoption of regulations that will enhance energy efficiency of the Russian economy and increase use of renewable energy sources. Farms and community might be interested in new technologies and, at the same time, could be supported by government and investors.

3.3. Laws considering biogas production and fertilizer use of cattle manure/digestate

Biogas plant production covers several industries: recycling industry (the market of recycled materials, waste legislation, regulations on biowaste), energy industry (energy prices, terms, EU legislation in the energy sector) and "green" agriculture (soil and water protection, regulations of organic fertilizers, decisions about the materials for fertilizer, hygiene laws and disposal of fallen animals).

The most important points in the legislation are (Langen 2007, 11-12):
- legislation on waste;
- government regulations on biowaste;
- resolution on organic fertilizers and fertilizer for EU regulations in the field of hygiene.

There are two main regulations on biowaste treatment and utilization (Consultant Plus):

- The law of zero waste technologies and waste recycling;
- The law on fertilizers materials.

3.4 Regulatory methods for biogas production

3.4.1. Best practice case. Regulatory system in Germany

For the best practice the German case study was taken as Germany is the European leader in biogas production. Currently Germany produces 61% of the biogas in Europe and being also one of the largest fleets of biogas electricity generators in the world. Why the country has succeed in this field and what regulation system exists?

Anaerobic digestion, i.e. biogas technology, has been actively used in the waste management since disposal of municipal solid waste was banned in Germany. The Federal Government's regulations on recycling and waste management and disposal of biowaste and sludge focus on achieving a closed cycle system and generate quasi zero-waste (Fig. 2) (Poeschl 2011, 23-26).

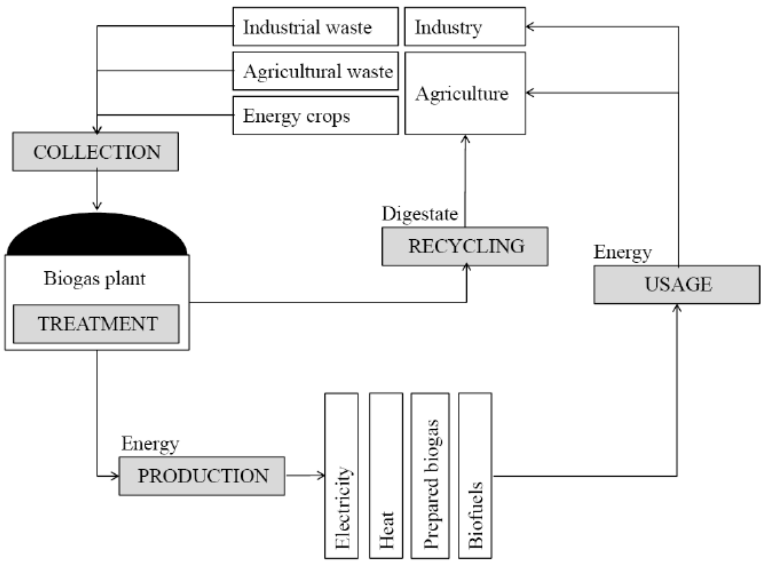

FIGURE 2. Closed cycle of matter designed to generate zero-waste

Policy framework

Germany has developed a policy to support biogas utilization and consequently its production. The policy is a system with many tools that help to meet environmental objectives.

The EU Greenhouse Gas Emissions Trading System in the National Environmental Policy is to meet the set targets in the Kyoto protocol. Large power plants (>20 MW thermal capacity) prescribed maximum emission allowance, but additional emission allowance can be purchased through a dedicated stock markets, while emission reduction credits can equally be traded. Methane content in the digestate is reduced by 95%, which is the key advantage of biogas in emission trading (Emissions trading 2012, 5)

The Renewable Energy Resource Act (EEG) favors biogas utilization for CHP. The output of CHP generation from biogas is about 2/3 heat and 1/3 electricity at 80-90% efficiency (FNR 2006, 8), so it provides scope for operational efficiency enhancement and cost reduction.

The price of grid-injected biomethane is not guaranteed as the fixed electricity feed-in tariff. It depends on market prices and the sale as “green energy”. The last version of the Regulation on Access to the Natural Gas Grid (Gasnetzzugangsverordnung;

GasNZV) from 2010, however, allows biomethane producers to inject biomethane in the natural gas grid and regulates the costs for grid access: for access to the grid of less than 1 km distance, 75% of the costs for the grid access has to be paid by the grid operator, 25% (up to 250 000 €) by the biogas plant operator (Fulton 2012, 14).

Upgrading of biogas to natural gas quality (bio-methane – 95% of CH4, hydrocarbons 2.7% and small amount of nitrogen (N2) - 1.6%, carbon dioxide (CO2) - 0.7% (Embridge gas 2012) in Germany is governed by the regulations for access to natural gas network (GasNZV) and by payments for natural gas network (GasNEV). These regulations help to set cost-intensive biogas upgrading technology (Table 6), that is might be economic just for large-scale biogas systems (Helm 2008, 15). The break-even point for economic bio-methane production specifically for injection into the national grid is in the region of 1 MW at volumetric flow of at least 250 m3/h to more than 2 MW for 500 m3/h (FNR 2006b, 13).

TABLE 6. Cost elements for upgraded biogas depending on different factors

Cost elements for upgraded biogas	Cents per kWh	Influencing factors
Biogas production costs	3.5-8	Feedstock type, plant size, volume flow of biogas
Preparation costs	2-6	volume flow of biogas
Grid injection/conveyance fees	0.3-2	volume flow of methane, transmission distance
Total	5.8-16	

German tariff structure

1. The feed-in tariffs for biomass depend on feedstock, conversion technology and size category. The base rates for biogas are set according to four categories (Table 7) (Fulton 2008, 13).

TABLE 7. Base rates for biogas generation

Category	**Base rate, € ct/kWh (2012)**
150 kW <	14,3
150-500 kW	12,3
500 kW – 5 MW	11
5-20 MW	6

2. Bonuses for specific feedstock

There are two feedstock classes that can affect bonus payments depending on biogas plant size (Table 8) (Fulton 2008, 14).

TABLE 8. Bonuses for specific feedstock

	Class I	Class II
Bonus payment	4-6 € ct/kWh	6-8 € ct/kWh
Feedstock	Grains and cereals	Animal manure, plant waste

There is a different tariff of 25 ct/kWh for small-scale (75 kW) biogas plants (Fulton, Capalino 2012, 14).

Not only Germany, but also many European countries have established favorable conditions for electricity production from biogas (Table 9).

TABLE 9. Examples of feed-in tariffs in Europe (c/kWh)

Country	Austria	Germany	France	Spain	Italy	Netherlands
Agriculture 1000 KW	12.38	8.51-17.51	7.5	10.75-15.89	22-28	7.9

3.4.2. Legal basis for permitting of biogas investment projects in Germany

The installation and operation of biogas plants in Germany always requires permission from the public authorities. The minimum requirement is a building permit (either as independent permit or in the framework of the BImSchG as described below). The permit procedure depends on the size and location of the biogas project as well as on the feedstock material. The German legislation specifically favors biogas installations.

There are two options for permit procedures which are based on the following legislations:

- Federal Emission Control Act (Bundes-Immissionsschutzgesetz; BimSchG)
- Federal Building Code (Baugesetzbuch; BauGB)

The BimSchG is a law to control harmful environmental impacts such as air pollution, noise, vibrations and other impacts. It is one of the most important laws in the environmental area, which regulates emission issues in general. Specific technical issues which are important for practical applications are regulated in several implementing ordinances (Durchführungsverordnungen; BImSchV) under the BimSchG. The classification if permit procedures for biogas plants are based on the BimSchG or on other legislation such as on the Federal Building Code is defined in the 4th BImSchV (Ordinance on Installations Requiring a Permit).

In comparison to the permitting procedure under the BauGB, the permitting procedure under the BImSchG is more sophisticated and complex. If a biogas plant has to undergo the procedure according to the BImSchG, the permit automatically includes the permit for building and the compliance with Regulation EC/1774/2002 on "laying down health rules concerning animal by-products not intended for human consumption". Thus, the biogas project only requires one single permit after BImSchG. Depending on the amount of daily treated waste materials, a simplified or a formal permitting procedure within the BImSchG is applicable. The formal procedure is more time intensive since public participation is required.

The permitting procedure under the BauGB, usually for smaller biogas plants, is simpler than the permitting procedure under the BImSchG. In order to determine compliance with the BauGB, two issues have to be clarified: is the plant permissible regarding the building development plan, which answers the question whether the location is suitable for the plant and regarding the building regulation which determines how the plant has to be installed (Kirchmeyr 2010, 6-9).

4. ENVIRONMENTAL LICENSE SYSTEM. AUDIT AND COMPANY ACCREDITATION

On the stage of biogas plant implementation, the first thing the company faces is the legal permit and further project regulation. In this chapter legislative basis in Russia was considered and existing weak points were shown.

4.1 Biogas plant implementation in Russia. Legislative basis

As it was said before, the institutional environment for biogas projects is not developing in Russia and the legislative base for biogas production remains undeveloped and requires amendments to the law and new regulations for the governance.

As an example may serve a biogas plant project "Baytsury", which was launched in 2012. The project started with an analysis of existing technologies adhered to the pig-breeding complex and technological cycle of waste production. After that the technical task was prepared and it was based on German technology. There occured a problem with preparation of construction documents as there were neither standards nor regulations for this kind of projects. For the managers of the biogas plant “Baytsury” there were some doubts how to qualify such production, whether it is dangerous or not, should it be licensed or not. Finally it was determined that the biogas plant operating organization imposes requirements to obtain the following licenses:

- A license to operate hazardous waste of hazard class 1-4;
- A license to operate hazardous industrial facilities.

The example shows that it is still unclear how to implement biogas projects in Russia. It might be that the Russian Federation will consider the European experience or experience of Ukraine. To get the license for the production, storage and selling of biogas in Ukraine the organization has to get the permission from the State Fire safety Service, State Supervision of Safety in Industry and the State Sanitary-Epidemiological Service. All these bodies must give permission (or a positive opinion) that the conditions of production and sale of biogas do meet the health and safety requirements, the fire safety and the health requirements (Naida 2009). The organization must obtain permission from the Ministry of Ecology as well.

According to the Federal law № 250 "On Amendments to Certain Legislative Acts of the Russian Federation in due to the implementation of the reform measures of the Unified Energy System of Russia" bonus to the price of energy from renewable energy sources will be paid to qualified generators as a markup to the wholesale price.

These prices are fixed value that varies for different types of renewable energy sources, and they must be approved by decision of the government.

To get the bonus a generating company should apply from the issuing body that produces renewable energy certificates ("green" certificates) and conducts register of them. “Green" certificates are records in the electronic database, as well as in the case of shares. The calculation of the bonus is performed by multiplying the total number of the certificates by government allowance.

Thus, the "green" certification is a new tool to regulate electricity markets in Russia and can be used for various purposes related to the production and consumption of energy from renewable energy sources. The certificate has some functions:

- defines the environmental and economic value of energy from renewable energy sources;
- entitles the biogas plant to receive a bonus from selling the energy;
- serves as a tool of statistical accounting of energy production volume, estimates the achievement of national objectives in this area;
- provides control of fulfillment of the adopted voluntary commitments to renewable energy use.

The Russian system of "green" certification has some differences from similar type of international systems. For example, in Germany the certificate is annulled immediately while the Russian one can be just marked as an expired. Russia's "green" certificates will be extinguished only after confirmation of support or after expiry of their validity. In the future, these Russian certificates can also be used to confirm the acceptance of voluntary commitments on energy consumption from renewable energy sources by the company.

5.0 MATERIALS AND METHODS

In this chapter the case farm was described. The model is used to demonstrate investment and biogas plant capacity was shown and the data used as parameters in economic scenario tool was described.

5.1 Case-farm Partizan and city of Osmino

In this study the agricultural enterprise JSC Partisan has been selected as a case. It locates in Leningrad region, Luga district, village Osmino. The main activity of the company is cattle husbandry and potato cultivation.

The annual average number of cows - 760 cows and 860 calves. Average number of employees at the end of the year 2011 - 228. There are also small milk industry equipments producing dairy waste. The amount of dairy waste is based on indicative estimation.

According to the data from the literature (Kapuinen 1999, 21-23) and statistics from the Finnish ministry of environment (YM), the average amounts of animal manures are (Table 9.1):

TABLE 9.1. The average amounts of animal manures produced per animal

Material	**Amount of manure (m^3/year)**
Cattle slurry	~ 20 m^3
Chicken manure	~ 0,2 m^3
Pig manure	~ 6,6 m^3

The analysis made in ESBIO–project in South–Savo provided data of the animal manure quality (i.e., TS, VS), and the energy self-sufficiency of local farms was also estimated.

Total amount of manures and other organic by-products produced at the farm is evaluated at 39,000 t/a (Table 10).

TABLE 10. Materials produced at the farm

Material	Heads	Manure per head	Amount (t/a)	Expected (TS; %)	VS % % TS	Biogas yield, l/kg VS
Cattle slurry	1500 cows	~20m3/cow/a	30,000	6,5	84,6	90-310
Chicken manure	20 000 chicken	~0,2m3/chicken/a	4,000	25,0	72,0	310-620
Pig manure	300 pigs	~ 6,6 m3/pig/a	2,000	7,0	85,7	340-550
Vegetable wastes from the farm			2,000	3,5	88,6	330-360
By-products from dairy industry			1,000	12,0	91,7	320-450
In total:			**39,000**			
TS of feed mixture			**8,41%**			

The Case farm's energy need can be reviewed from the Table 10.1.

TABLE 10.1. Energy consumption of the case farm

	Amount	Total price
Electricity	281 MWh	176,6 t €
Gasoline	209 518 liters	86,8 t €
diesel	224,693 liters	100 t €

The grants received by Partizan during the 2011 are represented in the Table 10.2.

TABLE 10.2. Received grants of the case farm

Budget type	Amount of money, t €
local budget	24,3
regional budget	95,4
federal budget	109,2

5.2. Model used in comparison

The model used in comparison defines the basic technical solutions based on the materials available in the farm and how the end products are planned to be utilized within the limits of local legislation and regulations. For this case the biogas plant treating 20 000 t/year was chosen. The choice was made because of the two main reasons, which are bench mark targets and suitable size for average Russian farms. The indicative economic analysis was made on the base of technical characteristics and some indicative environmental aspects. The tool for the analysis was developed in the Mikkeli University of Applied Sciences. It is used to examine the cost-effectiveness of the farm-scale biogas plants in South-Savo region in Finland (Soininen H., Luste Soininen 2012; Soininen H., Ranta-Korhonen, T. & Luste, S. 2012; Luste, S., Soininen, H., Seppäläinen, S. 2012). To provide more reliable economic analysis, the European experience was considered with corrections on Russian prices.

The estimated investment cost of biogas plant (with CHP-unit) is 1,16 (1,25) Million €. These figures are based on the biogas clarifications and already implemented and bench marked plants in Finland. When the bench marked prices are compared, the value of the work is screened to be 1/3 of the total investments. To make the cost more adequate for Russian biogas plant, the average salary differences between the Finnish and Russia are taken into consideration. Part of the work, for example the maintenance of CHP-unit, is ordered abroad. Differences in taxes, gate fees, and energy prices are taken into consideration as well.

5.3 Parameters used in Scenarios

The economic evaluation is provided with an economic scenario tool described above. The indicative model takes into consideration the following parameters:

- Materials available and their characteristics (TS, methane production content, steady production feasibility)

Biogas can be produced from a wide range of waste material. Anaerobic digestion is particularly suited to wet organic material. For this case materials like cattle slurry, chicken and pig manure, vegetable wastes from the farm and by-products from dairy industry were taken into consideration. Beside the amount of raw material TS and VS were also taken into account.

- Type of the energy production plant (heat and/or Heat and electricity) with its technical characteristics
- Operating costs (Plant heat and electricity consumption, transportation, labor, maintenance)
- Energy price
- Gate fees
- Investment costs
- Financial support (from the ministry, government support funding)

The possible support amounts for the scenarios are estimated according to the Russian financial sources and the bench marked projects for Finland:

a) According to National Reserve Bank and Alfa Bank, the possible level of loan could be 80%. Russian banks normally demand 20-30% funding from the total investments before they can finance money for the project.
b) 50-60% based on the comparable project in Finland.
c) 20% more according to annual increase of agricultural support money (see the Table 2).
d) from the Investment Fund of the Russian Federation in the amount of 30-50% of the capital investment.

The other sources of the co-financing are:

a) the program "Improving the energy efficiency of the Russian Federation for the period up to 2020" from the budget of the Russian Federation;
b) Commercial banks loans or attracting "bound" loan of foreign funds to supply the equipment (Energy saving agency 2010).

In 2010 14 project applications were approved by the Commission of Energy Conservation Agency (that finances energy efficiency projects at the expense of the funds provided for the energy-saving technologies implementation). The total funding is 434.5 million rubles or 31 million rubles (750 thousand Euro) per 1 project (Energosvet 2010).

6.0 RESULTS AND DISCUSSION

6.1 Technical analysis

The technical analysis at this step is only an outline to support the economical calculations. The more detailed technical planning will take a place when project is estimated to be beneficial.

The biogas plant treating 20 000 t/year was chosen as an example case. The minimum HRT is 20 days. The size was chosen due to the bench marked Finnish biogas plants processing 20 000 t/ year and due to the storage possibilities. Also 20 000 t/ per year treating plant is the more suitable size for the average farm sizes in Russia.

The biogas plant will treat the waste from the agricultural enterprise “Partizan”. The substrates are treated free of charge. The suitable material for the anaerobic digestion is produced nearly 40 000 t per year. The feed mixture consists of cattle slurry, pig and chicken manure, vegetable waste and by-products from dairy industry as well. However, most of the materials (~ 30 000 t/per year) is cattle manure, which energy production potential is the lowest (130-240 m^3 CH_4/tVS_{added}; Ahring 2001, 51; Amon 2006, 19-21; Angelidaki and Ahring 2000, 29; Lehtomäki 2007, 11; Mladenovska 2006, 18; Møller 2004, 36; Nielsen 2004, 17), when compared to the rest of the materials available. Thus, the feed material was studied according to the relations of the produced material (Table 11, Table 12), as well as according to the estimation of the optimal feed mixture ratio based on the literature (F. J. Callaghan, 2002, 71-77; Luste S, Seppalainen S, Soininen H, 2012), where all the energy effective manure produced (chicken, pig) is utilized and the amount of cattle slurry is reduced.

The treated feed mixture from JSC “Partizan” is supposed to have TS content of 8,41 and with optimized feed mixture 10,23 %. The feed mixture is suitable for the wet digestion. The feedstock needs to be a liquid mixture with appropriate moisture content. The mesophilic mix tank digesters (the most commonly used today) operate best with a mixture with TS 4-15%. Digesters require different moisture contents, depending on the design and operation of the system.

TABLE 11. Feed mixture composition (based on ratios material produced)

Material	Amount (t/a)	Expected (TS; %)	VS % % TS*
Cattle slurry	15,000	6,5	84,6
Chicken manure	2,000	25,0	72,0
Pig manure	2,000	7,0	85,7
Biowaste	1,000	3,5	88,6
By-products from dairy industry	0,500	12,0	91,7
in total	19,500		
TS of feed mixture	8,41 %		

*percent of VS in the TS

TABLE 12. Optimized feed mixture composition

Material	Amount (t/a)	Expected (TS; %)	VS % % TS*
Cattle slurry	11,000	6,5	84,6
Chicken manure	4,000	25,0	72,0
Pig manure	2,000	7,0	85,7
Biowaste	2,000	3,5	88,6
By-products from dairy industry	1,000	12,0	91,7
in total	20,000		
TS of feed mixture	10,23 %		

*percent of VS in the TS

Based on the feed volume and mixture composition, the needed reactor volume was defined. The starting values for two feed mixture options are:

	Amount	TS	VS%%TS*	HRT, days	OLR, kgVS/m^3 d
1	20,000	10,23%	80%	20	2,5
2	19,500	8,41%	81%	20	2,5

*percent of VS in the TS

1. The reactor volume based on HRT:

$$\mathbf{V = Daily\ feed \times Time}$$

Daily feed is 1) 54.8 m^3/d; 2) 53,4 m^3/d.

V_1 =54.8*20=1096 m^3

V_2=53,4*20=1069 m^3

2. The reactor volume based on OLR:

$$V = VS \div OLR$$

1) Daily feed (1) is 54.8 t/d = 54800 kg/d.

   Daily feed (2) is 53.4 t/d = 53400 kg/d.

2) The amount of VS fed into reactor is:

$$VS = Daily\ feed \times TS \times VS\%\%TS$$

   VS_1=54800 kg/d * 0.1*0.80 = 4384 kgVS/d.

   VS_2=53400 kg/d * 0.08*0.81 = 3461 kgVS/d.

   Maximum OLR is 2.5 kgVS/m^3 d.

   Reactor volume based on OLR:

   V_1=4384/2.5 = 1754 m^3.

   V_2=3461/2.5 = 1385 m^3.

The reactor volume is chosen based on OLR. Thus the approximate reactor volume is 1754 (1385) m^3.

The one of the important economical constituents is heat and electricity production. The scenario tool takes this into account. The starting values for energy calculation are shown in the Table 13:

TABLE 13. Starting values for energy calculation

	Value
Caloric value, [MWh/m^3]	0,01
CHP-unit efficiency	0,85
Heat	0,5
Electricity	0,35
Efficiency of heat boiler	0,9
Efficiency of the biogas plants own efficiency	0,7
Efficiency of scrubber	0,98
own consumption, electricity	0,17
own consumption, heat	0,83

Own consumption of the plant

$$\boldsymbol{C = Et \times (1 - \eta) \times Co};$$

where *Et* – total CHP production, Et=3601 MWh/a;

η – own efficiency, η=0.7;

Co – own consumption.

Electricity consumption: C_e=3601*(1-0.7)*0.17=**184** MWh/a

Heat consumption: H_e=3601*(1-0.7)*0.83=**897** MWh/a

With the scenario tool the electricity and heat production was calculated for CHP-unit and for heat boiler.

1. **CHP-Unit**

- Electricity production

$$\mathbf{E = Ge * Electricity};$$

where Ge – grossenergy, Ge=4236 MWh/a

E=4236*0.35=**1483** MWh/a

- Heat production

$$\mathbf{H = Ge * Heat};$$

H=4236*0.5=**2118** MWh/a

2. **Heat boiler**

- Heat production

$$\mathbf{H = Ge * \boldsymbol{\eta}};$$

where η - efficiency of heat boiler

H=4236*0.9=**3813** MWh/a

Considering own consumption of the plant, we can assume that the amount of salable energy will be:

$$\boldsymbol{Es = E - Ce;\ Hs = H - Ch}$$

1. **CHP-Unit**

Es=1483-184=1299 MWh/a

Hs=2118-897=1222 MWh/a

Total: 1299+1222=2512 MWh/a

2. **Heat boiler**

Hs=3813-897=2916 MWh/a

The average electricity need is 281 MWh (Table 10.1), thus there is a sellable energy surplus 1200-1300 MWh/a. So the part of produced energy will cover farm's needs and the surplus can be sold to the net.

6.2 Economic analysis

To understand different points to be managed for the efficient biogas plant work, various scenarios were considered:

1) "The effect of support" scenario;
2) "The effect of tariff" scenario;
3) "The effect of gate fees" scenario;
4) Combinated scenario.

All scenarios were estimated by the economic tool. According to the economic tool described above and the literature (Luste, Soininen 2012; 9; Soininen, Luste 2012, 4; Soininen, Ranta-Korhonen, Luste 2012, 14; Luste, Soininen, Seppäläinen 2012, 11), the comparison is made for both only heat producing and heat & electricity producing plant. It should be noted that optimal feed mixture would have improved also the economic benefits, but the following scenarios are calculated according to the production ratios of materials.

Scenario 1. The effect of support.

Based on the bench marked project in Finland, the possible level of support can be 50-60% of total investment cost. It is assumed, that Russian banks normally require 20-30% funding from the total investments before they can finance money in the project. The support can be increased by 20% due to the increase of agricultural support money (please, see chapter 2).

It should be noted that the investment cost for a CHP-unit is higher than for a heat boiler, as well as the maintenance cost and electricity consumption is increased.

TABLE 14. The effect of support for the plant producing heat and electricity via CHP -unit

Own co-financing %	Support	Loan	Gross income/a
0	20	80	-45 836
	30	70	-29145
	50	50	4238
5	20	75	-37491
	30	65	-20799
	50	45	12583
10	20	70	-29145
	30	60	-12454
	50	40	20929
15	20	65	-20799
	30	55	-4108
	50	35	29275

Based on the data from the Table 14, the following charts have been created:

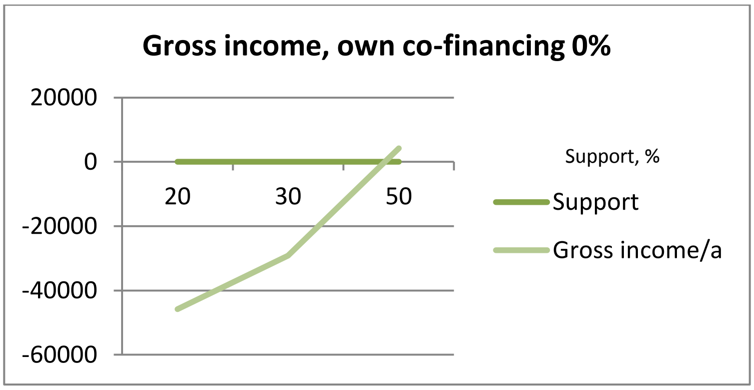

FIGURE 3.Gross income with different levels of support, own co-financing is 0%

With no own co-financing, gross income for the biogas plant producing heat and electricity via CHP – unit would be positive when the support is about 50%.

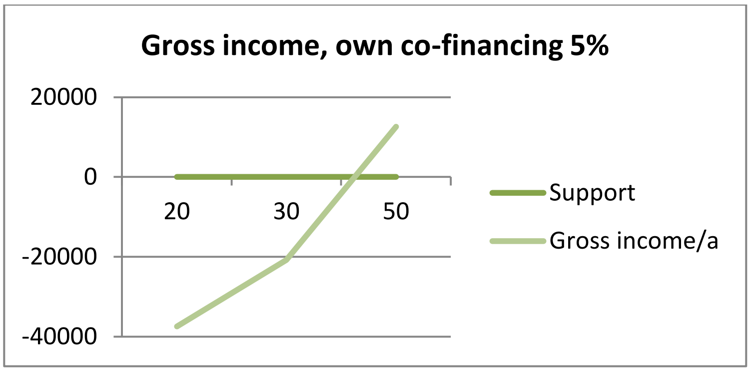

FIGURE 4.Gross income with different levels of support, own co-financing is 5%

With the own co-financing of 5%, gross income for the biogas plant producing heat and electricity via CHP – unit would be positive when the support is about 42%.

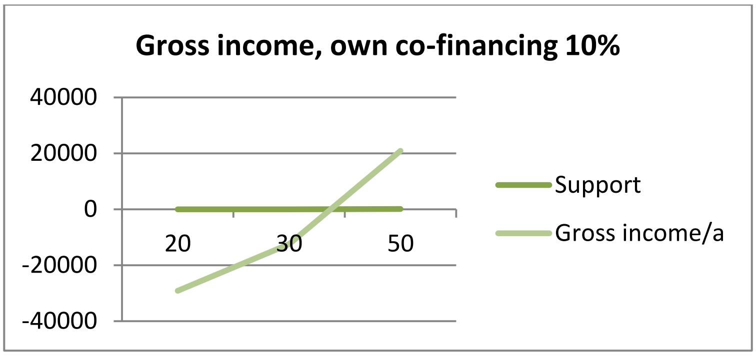

FIGURE 5. Gross income with different levels of support, own co-financing is 10%

With the own co-financing of 10%, gross income for the biogas plant producing heat and electricity via CHP – unit would be positive (i.e. the project is profitable) when the support is about 37%.

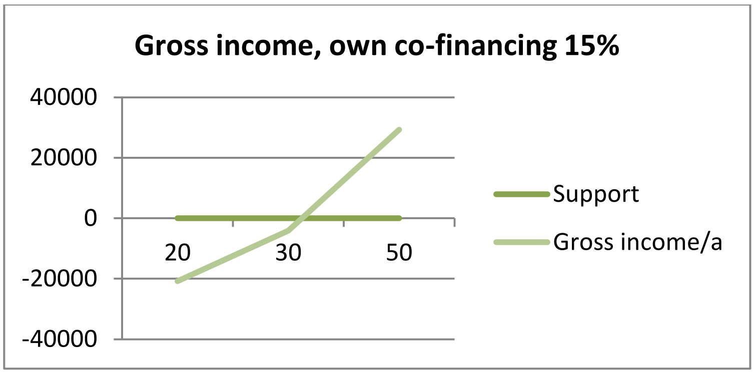

FIGURE 6. Gross income with different levels of support, own co-financing is 15%

With the own co-financing of 15%, gross income for the biogas plant producing heat and electricity via CHP – unit would be positive (i.e. the project is profitable) when the support is about 30%.

Thus, the needed support for the efficient biogas plant producing heat and electricity via CHP –unit varies from 30% to 50%, depending on the own co-financing possibility.

The same analysis has been provided for biogas plant producing only heat (Table 15).

TABLE 15. The effect of support for the heat producing plant

Own money %	Support	Loan	Profit/a
0	20	80	-21 346
	30	70	-5996
	50	50	24704
5	20	75	-13671
	30	65	1679
	50	45	32379
10	20	70	-5996
	30	60	9354
	50	40	40054
15	20	65	1679
	30	55	17029
	50	35	47729

Based on the data from the Table 15, charts have been created:

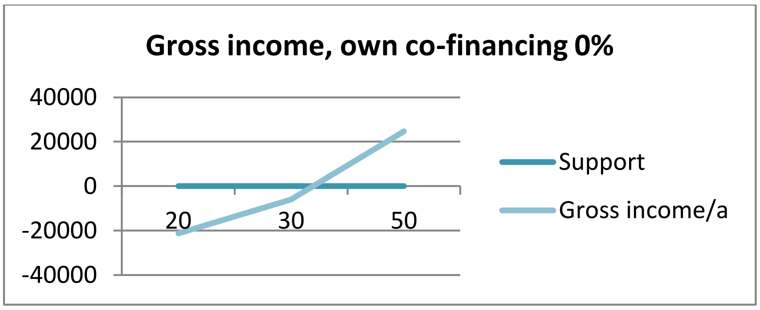

FIGURE 7. Profit with different levels of support, own capital is 0%

With no own co-financing, gross income for biogas plant producing heat would be positive (i.e. the project is profitable) when the support is more than 30%.

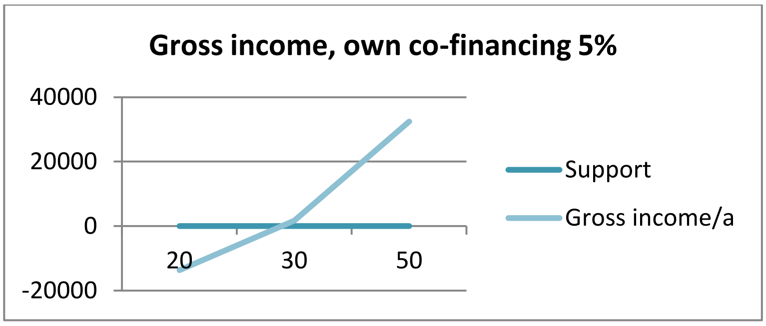

FIGURE 8. Profit with different levels of support, own capital is 5%

With the own co-financing of 5%, gross income for biogas plant producing heat would be positive (i.e. the project is profitable) when the support is 30%.

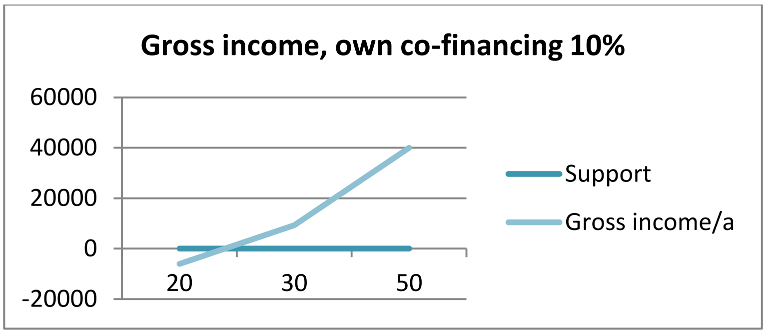

FIGURE 9. Profit with different levels of support, own capital is 10%

With the own co-financing of 10%, gross income for biogas plant producing heat is positive (i.e. the project is profitable) when the support is about 25%.

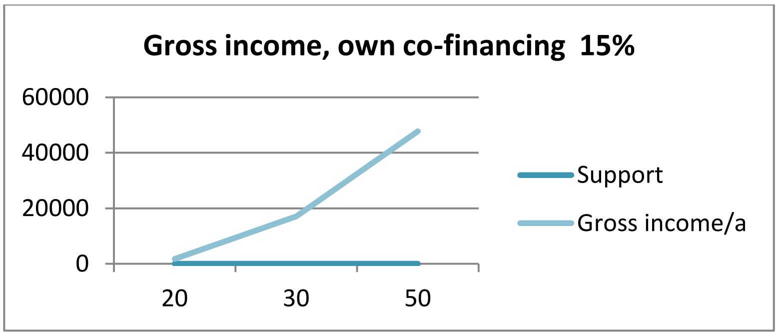

FIGURE 10. Profit with different levels of support, own capital is 15%

With the own co-financing of 15%, gross income for biogas plant producing heat would be positive (i.e. the project is profitable) with the minimal support of 20%.

As a result it is evident that the support of 30% is a critical point where the gross income is likely positive. Also have analyzed the table, the loan has to be less or equal 65% to lead to the profit.

Have analyzed the information about agricultural support in the Leningrad region and the grants received by the “Partizan” (Table 15.1), the total amount of annual grant equals with the support of 20% from the total investment costs (Table 15.2).

TABLE 15.1. Agricultural support and “Partizan” grants

	2011 Million €	2012 Million €	Amount of money, received by “Partizan” t €
Federal budget	53.65	51.2	109,2
Regional budget	48.8	58.5	95,4
Local budget	1.95	2.2	24,3
Total	104.4	111.9	**228,9**

TABLE 15.2. Financial support in money equivalent

Support	Total investment (heat &electricity plant) 1120 t €	Total investment (heat plant) 1030 t €
20%	**224**	**206**
30%	336	309
50%	560	515

Have defined the needed support for the plant producing heat and electricity via CHP –unit (50%) and only heat producing plant (30%), the enterprise “Partizan” needs to receive the grant at least during two years not to be unprofitable.

Scenario 2: The effect of tariff.

To analyze the effect of tariff on the profitability, different prices have been analyzed and the German price was taken for the highest possible tariff. The choice is made due to the leader position of Germany in the European market of the biogas production. Thus German biogas tariff is 16 €c/KWh or 160 €/MWh. The investment cost remains the same as in scenario 1. Aiming to show the way for higher profitability, the level of support is defined as 50% (possible support level, based on existing Finnish farms) and shareholders' investment is 10 %.

For CHP-unit the justified tariff will be 117 €/MWh, then the project payback period will be 10 years (Table 16).

TABLE 16. Tariff effect on profitability for the plant producing heat and electricity via CHP-unit

Sold electricity	66,15	100	117	120	160
Sold heat	65,6	99	116,5	119	157
profit/loss per year	20 929	81 506	112 563	117 530	187 831
payback period	54	14	10	10	6

For heat boiler the justified tariff will be 100 €/MWh, then the project payback period will be 10 years (Table 17).

TABLE 17. Tariff effect on profitability for heat producing plant

Sold electricity	66,15	100	117	120	160
Sold heat	65,6	99	116,5	119	157
profit/loss per year	40 054	109 652	146 118	151 327	230 510
payback period	26	9	7	7	4

Thus the green energy tariff is 33% higher than the national electricity price. It can be a bound for the biogas technology development in Russia. Either the national electricity should be higher to motivate people buy green energy or the government needs to support the biogas plants, paying the difference.

Scenario 3: The effect of gate fees

This scenario is based on the gate fee price and amount of substrate we treat. The various options for the amount of different substrates were analyzed. Meanwhile the total amount of waste remains the same. The prices for gate fees were taken from the Finnish and Swedish market data (Palm R., 2010, 9). The investment cost remains the same as in scenario 1, the level of support is defined as 50% and shareholders' investment is 10 %. The energy tariffs are calculated based on real national prices.

The analysis is provided for the plant producing heat and electricity via CHP-unit (Table 18) and for heat producing plant (Table 19).

TABLE 18. The effect of gate fees for the plant producing heat and electricity via CHP-unit

Material	Price, €/t	Amount, t/a			
		1	2	3	4
Vegetable wastes from the farm	6	1000	500	0	0
Sewage sludge	23	0	0	0	1500
By-products from dairy industry	12	500	1000	1500	0
Profit	**€/a**	**26929**	**32068**	**37207**	**48412**
Average gate fee	€/t	8,0	10,0	12,0	23,0

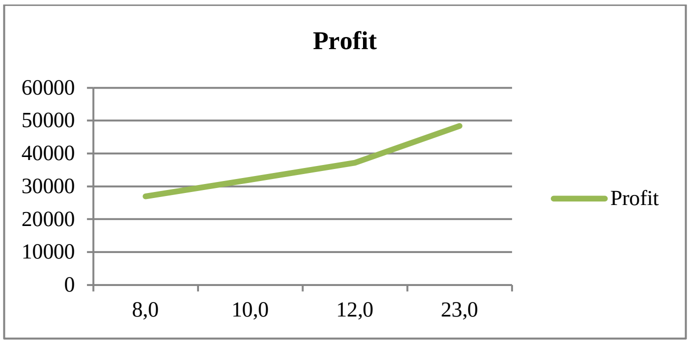

FIGURE 11. Profit function (average gate fee price) for the plant producing heat and electricity via CHP-unit

TABLE 19. The effect of gate fees for heat producing plant

Material	Price, €/t	Amount, t/a			
		1	2	3	4
Vegetable wastes from the farm	6	1000	500	0	0
Sewage sludge	23	0	0	0	1500
By-products from dairy industry	12	500	1000	1500	0
Profit	**€/a**	**46054**	**51369**	**56683**	**67453**
Average gate fee	€/t	8,0	10,0	12,0	23,0

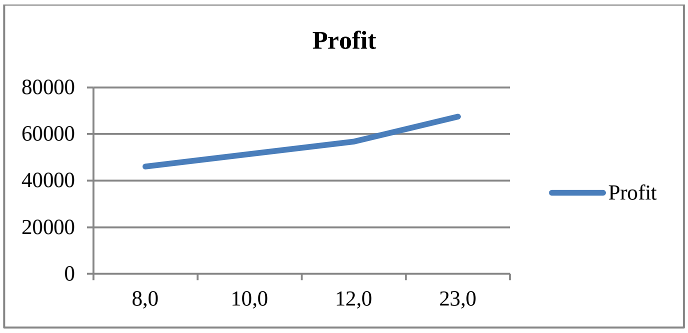

FIGURE 11. Profit function (average gate fee price) for heat producing plant

It is clear that the total profit increases linearly with gate fee increase, but the operating costs (transportation, maintenance) should be considered. Thus the sewage sludge with a gate fee of 23 €/t does not bring the profit twice higher than by-products from dairy industry with a gate fee of 12 €/t.

Scenario 4: The effect of combinated scenarios

Here the effect of insignificant value changes is shown. To compare for the base the initial support scenario was taken. The investment cost is the same, the level of support was defined as 50% and shareholders' investment is 10 %. The energy tariffs are calculated based on real national prices. Gate fee is considered for pig manure (1000 t/a), vegetable waste from the farm (1000 t/a) and by-products from dairy industry (500 t/a). Then the support has been increased by 20% (60% in total), green energy tariff is set 15% higher and vegetable waste was replaced with by-products from dairy industry (i.e. amount of by-products 1500 t/a). The total amount of treated substrate remains the same. The analysis is provided for CHP-unit and heat boiler (Table 20).

TABLE 20. Combinated scenario for the plant producing heat and electricity via CHP-unit and for heat producing plant

	Initial scenario	Changed scenario	
Possibly financial support	50	60	%
shareholders proportion	10	10	%
Sold electricity	66,15	76	€/MWh
Sold heat	65,6	75,4	€/MWh

Vegetable waste	1000	0	t/a
By-products from dairy industry	500	1500	t/a
profit/loss per year (heat and electricity via CHP-unit)	**26929**	**72234**	**€/a**
Payback period	42	16	year
profit/loss per year (heat producing plant)	**40054**	**93 190**	**€/a**
Payback period	26	11	year

Thus the increase of support by 20% and of green energy tariff by 15% with replacement of vegetable waste with by-products from dairy industry brings the increase of profit; thereby the payback period can be decreased by 2-3 times.

6.3 Ecological analysis

For the ecological assessment the environmental savings are determined and the valuation is provided. The environmental savings include saving of natural resources and raw materials, as well as the reduction of environmental pollution. The biogas plant construction brings environmental savings such as reduction of natural gas consumption, reduction of nutrient and CO, CO_2, NO, NO_2, NH_4 emissions as well as waste generation and its disposal.

The high nutrient emissions to the Baltic Sea are mainly originated from the agriculture and industries. 2/3 of the phosphor and more than 1/3 of the Nitrogen originated from the agriculture end up to the Baltic Sea. So the ecological effect will be enhanced by the proper waste treatment, stabilization and utilization techniques that eliminate nutrient leaching to the rivers, running to the gulf of Finland.

Biogas plant would decrease the greenhouse gas (GHG) emissions by 1.848 million kg of CO_2 eq./year (assuming 92.4 kg CO_2 eq./m^3 of slurry; Amon et al., 2006) from the storage and field applications of slurry/manure. This is a significant amount since these emissions have been estimated to be responsible for 80% of the direct agricultural emissions.

The adoption of biogas technology could also reduce indirect emissions from agriculture; emissions that are not usually included into GHG calculations (i.e., emissions from the energy consumptions of farms and production/transportation, emissions from petrochemical and fertilizer industries).

The biogas plant will solve the problem of manure utilization. For the ecological analysis the waste payment reduction was considered (Table 21). The electricity consumption reduction and emissions into the air and water are skipped due to impossibility to give accurate figures.

TABLE 21. Ecological analysis. Waste payment reduction.

№	Environmental effect	Environmental benefits		Economy, t €
		Amount	%	
1	2	3	4	5
3.	Waste payment reduction: Cattle slurry (IV) Chicken manure (IV) Pig manure (III) Vegetable waste (IV) By-products from diary industry (IV)	 11000 4000 2000 2000 1000	 100	
	Total:	20000		133,21

The fee for the waste disposal:

- waste of III hazard class is 497.0 rub/ton,
- waste of IV hazard class is 248.4 rub/ton.

Economy: (11000+4000+2000+1000)*248.2+2000*497=4467600+994000 = 5461600 RUB = 133,21 t €

7 RECOMMENDATIONS

In this study the cost-effectiveness and boundaries for biogas plant implementation were studied. The JSC “Partisan” was used as a demonstration case. The farm locates in the Leningrad region, Russia.

Four scenarios based on different aspects were tested. Every scenario included parameters that effect on the biogas plant performance and its profitability.

There are some legislative, financial bounds that the enterprise can’t manage by itself, but the understanding what parameter changes bring the profit increase can help to plan investments and further coordination of the project.

The first analysed issue was the support effect. Based on the bench marked project in Finland, the possible level of support can be 50-60% of total investment cost. It should be taken into the consideration that Russian banks normally require 20-30% funding from the total investments before they can give a loan for the project.

Three levels of support were analyzed (20%, 30%, 50%) for the heat producing plant and plant, producing heat and electricity via CHP-unit. The analysis showed that for heat boiler the support of 30% is a point where the profit is likely to be, and, at the same time, the loan has to be less or equal 65% to lead the enterprise to the profit. The needed support for the biogas plant with CHP-unit is 50%.

The second scenario is based on green energy tariff. Russia still doesn’t have a justified green tariff and the existing biogas plant sells the energy to the grid by the price 5% higher the national energy price.

Have analyzed different tariffs, for CHP-unit the justified tariff would be 117 €/MWh (payback period is 10 years), for heat boiler - 100 €/MWh, that is 33% higher than the national electricity price. It can be a bound for the biogas technology development in Russia. Either the national electricity should be higher to motivate people buy green energy or the government needs to support the biogas plants, paying the difference.

The next scenario reflects the gate fees. Some substrates are bought (e.g. energy crops), some are borrowed for free and some even generate income to the plant (e.g. waste). Facilities that take care of waste get economic compensation for the service, known as gate fees. Some feedstock has a variance in gate fees that implies bigger changes in the total cost than the variance of transportation distance. For these feedstocks, the gate fees are assumed to vary linearly, while each bearing the cost of its estimated average transportation distance. Thus the sewage sludge with a gate fee of 23 €/t does not bring the profit twice higher than by-products from dairy industry with a gate fee of 12 €/t.

In the last scenario the effect of value changes has shown. The analysis proves that the increase of support by 20% and of green energy tariff by 15% with replacement of vegetable waste with by-products from dairy industry brings the increase of profit; thereby the payback period can be decreased by 2-3 times.

The government should develop the renewable energy legislation that will define green tariff and solve uncertainties on the stage of biogas plant implementation. The biogas production is connected with waste management, as well as global warming issue.

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