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BIOGAS PLANT IN MUAS

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Abstract <p>Every year we produce about 3% more waste than the year before. This might not sound much but if we carry on at this rate, it means that we will double the amount of waste we produce every 25 years. Nowadays, when the whole world is trying to move to completely renewable energy sources, waste could probably play particularly important role, especially in biogas plants.</p> <p>The first and the most important aim is to find out if it is profitable to build a biogas plant in MUAS. Biogas plant has already proved that it is efficient way to use waste and make additional energy for heating and electricity. However in MUAS we have limited amount of biowaste so I will investigate how much energy would it be possible to get. The second aim is to learn what is the best way to use the energy from the plant - if it should be used in all buildings for electricity and heating or just for one (A)-building.</p> <p>In order to find the answers I will use the following methods. First of all I will collect data from restaurants about the amount of biowaste each day. The second method will be calculations of possible amount of energy. The next method is examination of biogas plant working technically. The last method is to get acquainted with biogas plant types, components of biogas and understand the work process of biogas plant.</p>		
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1 INTRODUCTION

1.1 General overview

Every year we produce about 3% more waste than the year before. This might not sound much but if we carry on at this rate, it means that we will double the amount of waste we produce every 25 years. Nowadays, when the whole world is trying to move to completely renewable energy sources, waste could probably play particularly important role, especially in biogas plants.

What if it is possible to get additional energy with waste that we have around us and take one more step to increase the use of renewable sources? Nowadays our society is still dependent on fossil sources, but renewable energy sources as biomass, sun or wind could change it faster than anyone expects. Biogas can not only contribute to the energy balance but also helps to protect environment from greenhouse effect and preserves natural resources.

Biogas plants are not an absolutely new thing. Each country already tries to increase the number of biogas plants and in this way achieve the goals of renewable energy directive of final energy consumption by renewable energy sources. Finland is one of the countries which uses most renewable energy sources and in 2012 it was 14,1% of gross final energy and now it is already >2% above of interim target.

In my Bachelor's thesis I will analyze how biogas plant works technically – what are the types of biogas plants, techniques to treat waste and processes during waste treatment. I will also discuss the advantages and disadvantages of biogas plant, I will try to find out, how much energy it is possible to get from biogas plant which would be located in Mikkeli University of Applied Science (MUAS) area, and if we could use the bio-waste thrown from restaurants there.

1.2 Aims

This work has several important aims. The first and the most important aim is to find out if it is profitable to build a biogas plant in MUAS. Biogas plant has already proved that it is efficient way to use waste and make additional energy for heating and electricity. However in MUAS we have limited amount of biowaste so I will investigate how much energy would it be possible to get.

The second aim is to learn what is the best way to use the energy from the plant – if it should be used in all buildings for electricity and heating or just for one (A)-building.

1.3 Methods

In order to find the answers I will use the following methods. First of all I will collect data from restaurants about the amount of biowaste each day. The amount will be summed up.

The second method will be calculations of possible amount of energy. This information will be very important while investigating the answers to other questions, as amount of possible energy, if it would be enough energy for MUAS or just for A-building.

The next method is examination of biogas plant working technically. This one will help me to get acquainted with biogas plant types, possible materials to use in biogas plant and after all get familiar to the typical components of biogas.

The last method is to get acquainted with biogas plant types, components of biogas and understand the work process of biogas plant.

2 RENEWABLE ENERGY IN EUROPE

Nowadays more and more people and countries are getting closer to green energy and renewable energy sources, but a lot of them are still loyal to coal, oil and natural gas to fulfill all the energy needs but reliance on fossil fuels can be a big problem in the future as fossil fuels are finite resource.

Fossil fuels also causes air and produces greenhouse effect, however it could be changed easily if all the world begins to use renewable energy. In this chapter the use of renewable energy sources in Finland and Europe will be described.

Solar energy

From the solar energy is possible to produce energy for heating, lightning or cooling homes, it could also be used for electricity and a lot of other industrials processes. To get the benefit from the sun it is important to install solar panels. However, the efficiency of sun depends on the location. If in the specific location sun is not shining most of the seasons, other renewable energy sources can be used. In Finland during the last three years the use of solar energy increased from 13888 MWh to 16666 MWh. /1./

Wind power

Wind power in general is a form of solar power as wind is caused by heat from the sun. This kind of energy has already been used before to sail ships and drive windmills but nowadays it has been moved to another level and now wind energy is used by wind turbines and used to generate electricity. Nowadays wind turbines are installed in the sea, where is bigger potential of the wind, also in high level locations. To add more, wind power does not have any harmful effect to environment as it do not produce CO₂. In 2009 Finland have made 275000 MWh from wind, and now it is used 483000 MWh. /1./

Water

Water is also renewable energy source as it is all the time recharged by rain cycle. Furthermore, falling water downstream is the powerfull force. It could be used for generating electricity by water wheels that drives mechanical processes. Comparing to other renewable energy sources water has the lowest amount of solid waste during energy production. However, as the number of people in Earth rapidly increases, there is the chance, that in several centuries there will be a lack of clean water and it could became a non-renewable source. Finland in 2009 produced 12.5 TWh energy from water, however in 2012 this number decreased and there is 12.3 TWh of energy produced. /1./

Geothermal energy

The heat inside Earth produces steam and hot water that can be used to power generators and produce electricity, use it for home heating and power generation for industry. Geothermal energy is also environmental friendly, cost efficient and sustainable. Besides, geothermal energy also has a potential to reduce greenhouse effect and help to reduce global warming if it will be used more than fossil fuels. In 2009 Finland produced 2 TWh of energy from geothermal energy. Nowadays geothermal energy in Finland produces 3.5 TWh of energy. /1./

During the several years Finland had been paying attention to renewable energy, and each year the production of energy from renewable energy sources has been growing. In 20 years the use of renewable energy sources in Finland increased 2 times. In 1990 the total consumption of bioenergy was only 48 TWh, and in 2012 there was already 99TWh. The consumption of renewable energy in Finland is shown in figure 1. /1/

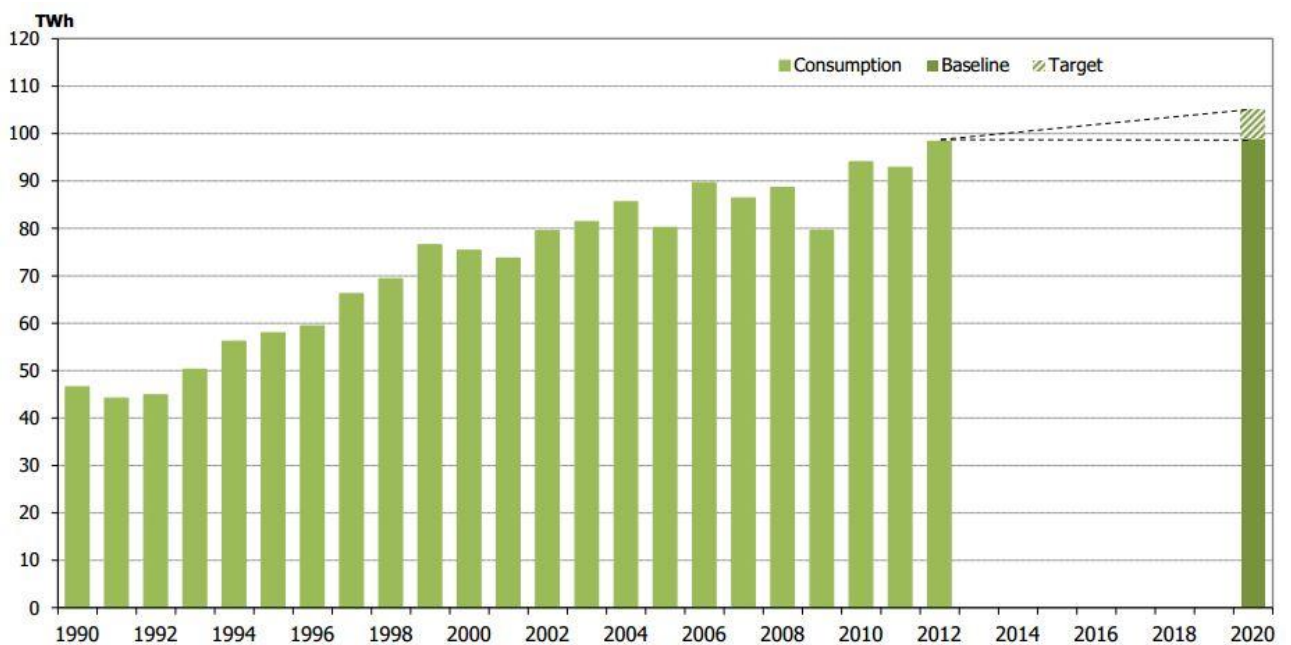


FIGURE 1. Total consumption of bioenergy in Finland /1/

2.1 Biomass energy

Biomass was an important source long time ago, people began to use wood for food or warming themselves before winter chill. Wood is still used not only in industry for example for paper but also in heating systems. However, there are other sources of biomass energy as food crops, grasses and other plants as well as agricultural and forest waste and residue, industrial wastes and organic components from municipal.

Moreover, biomass energy is not harmful for environment, to add more it has the potential to reduce greenhouse gas emissions. Biomass generates about the same amount of carbon dioxide as fossil fuels, but since new plants grows, carbon dioxide is removed from atmosphere. This repeating process is called carbon cycle.

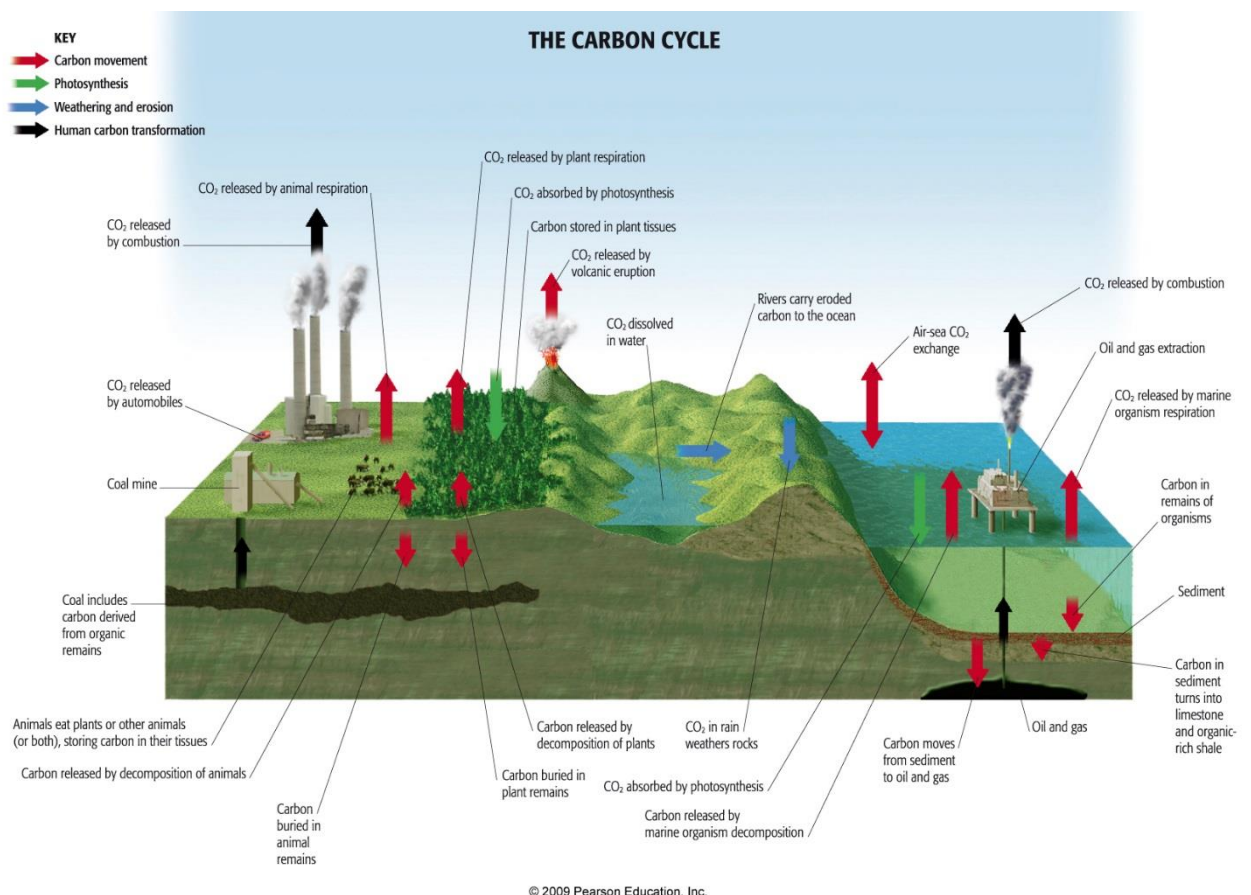


FIGURE 2. Carbon cycle /2/

The amount of CO₂ is dynamic, all the time changing into different carbon compounds. Trees and other plants stores CO₂, but when they dies and are used, CO₂ is emitted to atmosphere again.

Biomass can also be used in various ways. First of all biomass can be converted to liquid fuels for transportation. The most common types of biofuels nowadays are ethanol and biodiesel. It is also possible to burn biomass directly or convert it to gaseous or liquid fuels, and use it for heating or electricity. The last way to use biomass is to convert it into chemicals for making plastics or other products.

2.1.1 Biomass resources

Researchers had found the various types of biomass in different ways and then conclude it to four main types:

- Woody plants
- Herbaceous plants/grasses
- Aquatic plants
- Manures

Furthermore, each category can be subdivided according to moisture contents. /2./

TABLE 1. Biomass resources according to supply sector /2/

Supply sector	Type	Example
Forestry	Dedicated forestry	Short rotation plantations
	Forestry by-products	Wood blocks, wood chips
Agriculture	Dry lignocellulosic energy crops	Herbaceous crops
	Oil, sugar and starch energy crops	Oul seeds
		Sugar crops for ethanol
		Starch crops for ethanol
	Agricultural residues	Straw
Livestock waste	Wet and dry manure	
Industry	Industrial residues	Industrial waste wood
		vegetable waste from paper industries
Waste	Dry lignocellulosic	residues from parks and gardens
	Contaminated waste	Demolition wood
		Organic fraction of municipal solid waste
		Biodegradable landfilled waste and gas
		Sewage sludge

2.1.2 Biomass properties

There are specific properties of biomass sources that explains both the choice of conversion process and difficulties that may appear. The main material properties of interest, during processing as an energy source, connect to:

- Moisture content
- Calorific value
- Proportions of fixed carbon and volatiles
- Ash/residue content
- Alkali metal content
- Cellulose/lignin ratio.

For dry biomass conversion process these properties are of interest, while for wet biomass conversion, the first and last properties are primary./3./

3 BIOGAS IN EUROPE

The European Union policy has set the fixed goal to supply 20% energy from renewable energy sources. To reach this goal biogas can play an important role, as it is possible to make heat, electricity, vehicle fuel, chemicals or fuels cells from biogas. The most efficient way to integrate biogas into European energy sectors are to integrate biogas into the natural gas grid. Some of the countries has already integrated biogases into natural gas grid.

3.1 Germany

Germany is one of the country with mostly developed bioenergy sector, because of that, Germany has been chosen to compare with Finland. In 2011, The Federal Government of Germany made a decision to change the energy police and look at renewable energy sources as an opportunity for future energy production /4/. The Renewable Energy Directive 2009/28/EC made a goal to get 20% of renewable energy in final energy consumption by 2020.

3.1.1 Production of biogas

Most of the biogas plants were built in Germany. In 2013 there were 710 biogas plants and 610 of them operated fully with renewable energy sources. Mostly there are plants using agriculture, but also digest sewage sludge, biowaste, waste from industry and landfills.

TABLE 2. Status of biogas production in Germany from different plants 2012 /4/

Plant type	Number of plants	Energy production* (GWh/year)
Sewage sludge	1400	3100
Biowaste	95	4500
Agriculture	7800	29400
Industrial	250	3420
Landfills	400	550
Total	9945	40970

*= Produced energy as heat, electricity, vehicle fuel without efficiency losses

3.1.2 Utilization of biogas

German Energy Agency and German Biomass research centre collects data about use of biogas each year and they have already made a finding that biogas upgrading volume is increasing. In 2012 biogas was used for heat, electricity and vehicle fuel. For electricity 26.7 TWh, heat 14.0 TWh and for vehicle fuel 0.35 TWh.

TABLE 3. Utilization of biogas in Germany /4/

Utilisation type	GWh	%
Electricity	26650	65
Heat	14000	34
Vehicle fuel	350	1

3.1.3 Financial support systems

In Germany the Renewable energy Sources Act was made for financial support. The main purpose of this Act was to increase the use renewable energy sources in German electricity supply, reduce the costs of energy to the national economy and keep the development of technologies for using renewable energy sources. In 2012 this Act was amended and new bonuses were set.

TABLE 4. Renewable energy Sources Act 2012 in Germany /4/

Plant size	Basic bonus (EUR/kWh)	Substrate category I ¹ (EUR/kWh)	Substrate category II ² (EUR/kWh)	Bonus OFMSW ⁴ (EUR/kWh)	Upgrading bonus (EUR/kWh)
< 75 kW	0,25 ³				0.030 until 700 Nm ³ /h
< 150 kW	0.143	0.060	0.080	0.160	
< 500 kW	0.123	0.060	0.080	0.160	0.020 until 1000 Nm ³ /h
< 750 kW	0.110	0.050	0.080	0.140	
< 5 MW	0.110	0.040	0.080	0.140	0.010 until 1400 Nm ³ /h
< 20 MW	0.006	0	0	0.140	

¹ Biogas crops, > 60 wt% animal slurry

² Plants from Landscape conservation, clover, >60 wt% animal waste

³ >80% animal slurry (wt%)

⁴ Organic Fraction of Municipal Solid waste

3.2 Finland

Finnish government decided, that 10% of gas should be made from biomass by 2025. Moreover Finland aims that 60% of energy consumption will be from renewable energy sources in 2050 /4/. Finland has a lot of landscapes fulfilled with forests. It is possible to increase the use of energy made from wood, also a lot of biomass as branches, leaves could be found in the forests and used for energy production.

3.2.1 Production of biogas

In 2012 from biogas was made 568GWh from 73 different biogas production sites as shown in table 5.

TABLE 5. Status of biogas production /4/

Plant type	Number of plants	Energy production (GWh/year)
Sewage sludge, municipal	15	135
Biowaste, codigestion	9	112
Agriculture	8	4
Industrial wastewater	2	6

Landfills	39	312
Total	73	569

Finland could produce up to 4-6 TWh/year biogas from wastes and manures. In 2012 it was observed that crops do not play a significant role in renewable energy production. In addition, conclusion has been made, that forest-based biomass is more economical to raise the use of renewable energy in final energy production /4/. In the beginning of 2013, about 20 co-digestation plants were under construction or in planning phase /3/.

3.2.2 Utilization of biogas

The use of biogas was almost 83% of total production and biogas was mostly used for heat and electricity as shown in table 6.

TABLE 6. Utilization of biogas in Finland /4/

Utilisation type	GWh	%
Electricity	160	23
Heat	409	60
Vehicle fuel	4	1
Flare	115	17

During last two years the Finnish government is trying to promote the use of biogas as vehicle fuel /2/. In 2013 transport consumption of biogas was 10.8 GWh and it was 16.8 % more comparing to 2012. Traffic biogas was produced in five different plants and biogas is used only for transport. Biogas from 3 plants is transported to filling stations by biogas pipelines. From other 2 plants biogas is transported to filling stations by natural gas pipelines /6/. However, the use of biogas is increasing each year, and nowadays 0.68 TWh are used. The growth of biogas use in Finland is shown in figure 3.

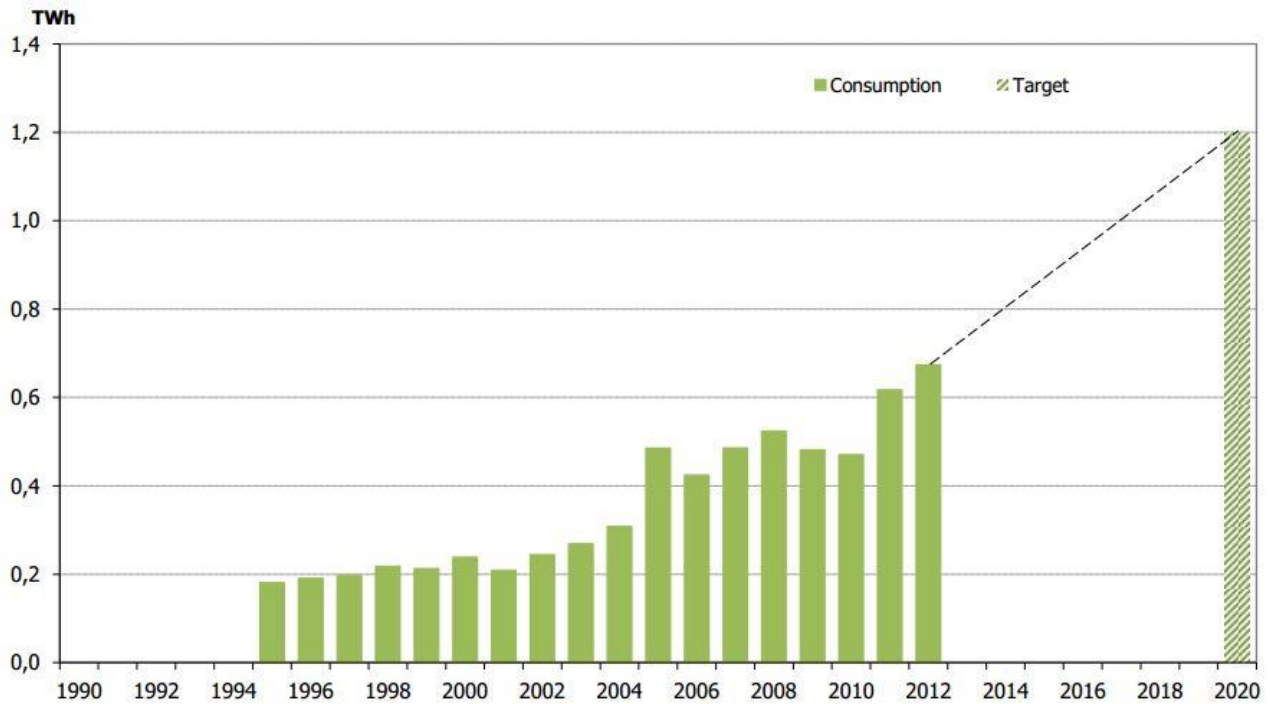


FIGURE 3. Biogas use in Finland /5/

3.2.3 Financial support systems

The Electric Market Authority of Finland sponsors new biogas plants, which can produce more than 100kVA, with feed-in tariff. It ensures a minimum price of 83.50 EUR/MWh electricity, but if generators exceeds 19 MVA no subsidy is paid. In the feed-in tariff system, subsidy will be approved for 12 years for electricity producer /4./.

The Ministry of Agriculture and Forestry supports farmers who want to have a biogas plants on own, but more than half biomass must be from their own farm (animals, crops, sludge) and more than 50% of produced heat and electricity should be used by the farm.

4 BIOGAS PLANT

Now there are several main types of biogas plants all over the world. Each time it is necessary to find the most suitable type in different case. One of my aims is to find out which type of the biogas plant is the most suitable and cost efficient for MUAS. To find out which type of biogas plants are most

cost efficient, in my Bachelor's thesis I will consider several factors, as energy production, requirements and used materials for constructing biogas plant.

In smaller areas with less waste or slurry to use low cost polyethylene tube digester can be used. This kind of system a hermetic isolated tank is obtained. Polyethylene tube digester has drainpipes serves, which works as inlet and outlet of the slurry. Tubular polyethylene is flexible, for this reason a firm is needed. This firm is necessary for accommodation of tank, that a ditch is excavated.

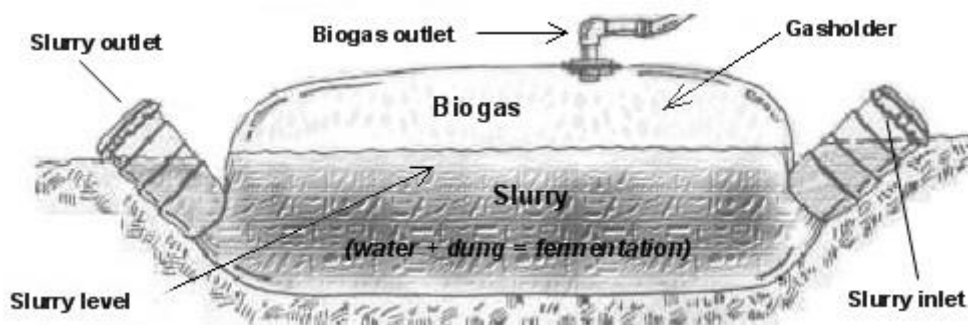


FIGURE 4. Polyethylene Tube Digester /7/

This system is simple to design and construct, also cost effective. On the other hand, it is short-lived because of the polyethylene plastic, which during some time can degrade. However, this system is not expensive to maintain, so main chamber is replaceable when needed.

Other not so popular types are horizontal plants, Earth Pit Plants and Ferrocement Plants.

Horizontal plants are chosen when unsound installation is needed and they are made from masonry or concrete. The construction of these plants are shallow, despite large slurry space, however, there can be problems with gas-space leakage and the elimination of scum is quite difficult.

Earth Pit Plants are recommended for installation in impermeable soil, which are above groundwater table. The cost of installation is low, but useful life is short. In addition it is only useful in suitable, tight types of soil.

Ferrocement Plants can be applied either as a self-supporting shell or earth pit lining. This plant gasholder needs special sealing measures. Ferrocement plants are low cost, needs low material input and mass production is possible. However, workmanship must meet high quality standards, this

construction technique is not properly time-tested. Also this kind of plants are recommended where special ferro-cement know how is available. /7./

4.1 Fixed-dome Plants

This type of biogas plant consists of a digester with a fixed gas holder which cannot move and it is located on the top of the digester. Another component is compensation tank, and slurry is displaced to compensation tank, when gas production begins. Gas pressure increases with the volume of gas stored and the height difference between the slurry level in the digester and compensation tank. /7./

The costs of fixed-dome biogas plants are low because there are no moving parts and rusting steel parts. The plant is constructed underground because of space saving and protecting from physical damage.

However, fixed-dome plants is not so easy to build construct as they should be build where experienced biogas technicians can supervise building process. Otherwise plants may not be gas-tight.

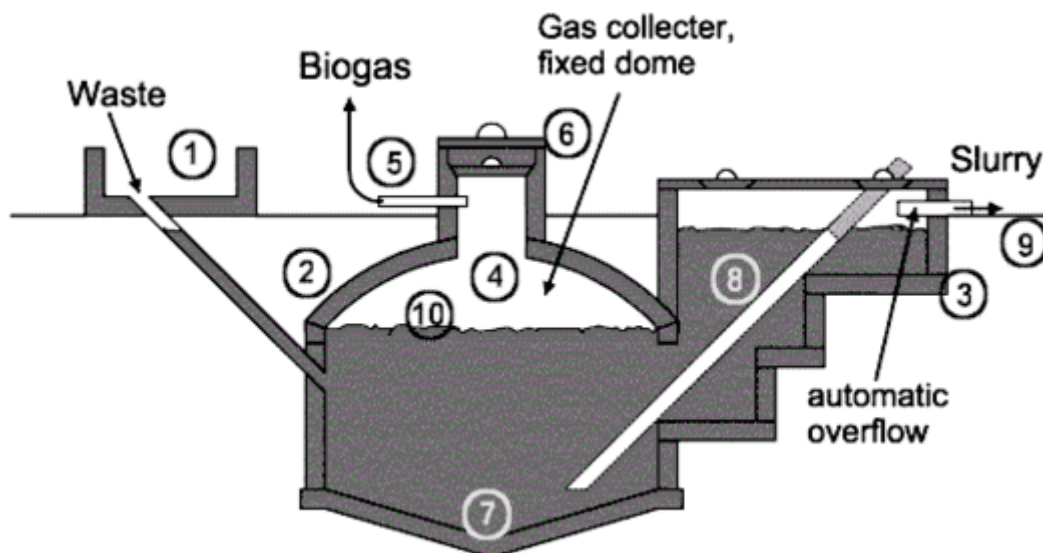


FIGURE 5. Fixed-dome biogas plant. 1. Mixed tank with inlet pipe and sand trap. 2. Digester. 3. Compensation and removal tank. 4. Gasholder. 5. Gas pipe. 6. Entry hatch, with gastight seal. 7. Accumulation of thick sludge. 8. Outlet pipe. 9. Reference level. 10. Supernatant scum, broken up by varying level. /8./

The digesters (2) of fixed-dome plants are masonry structures, structures of cement and ferro-cement exist. When choosing materials it is necessary to pay attention to technical suitability, cost-effectiveness, availability in the region and transport costs.

The top part of fixed-dome plant is gas holder (4) has to be gas-tight. Concrete, masonry and cement are not gas-tight. Before using biogas plant gas space must be painted with a gas-tight layer and for this can be used latex or synthetic paints. In case to prevent cracks that appears due to hydrostatic pressure in lower parts, weak-ring in the masonry of the digester can be used. This ring joins lower and upper parts of the hemispherical structure.

In the cold climate countries and locations fixed-dome plants should be covered with earth up to the top of gas-filled space to neutralize the internal 0.15 bar pressure. Due to economic parameters recommended minimum size of plant is 5 m³ and digester volumes up to 200 m³.

4.1.1 Function

A fixed dome plant includes a closed, dome-shaped digester with a non-movable, not flexible gas-holder and a displacement pit sometimes called compensation tank. The gas is kept in the upper part of the digester. When gas production begins, the slurry is displaced into the compensating tank. Gas pressure increases with the volume of gas stored. If there is little gas in the gas-holder, pressure is low /7/.

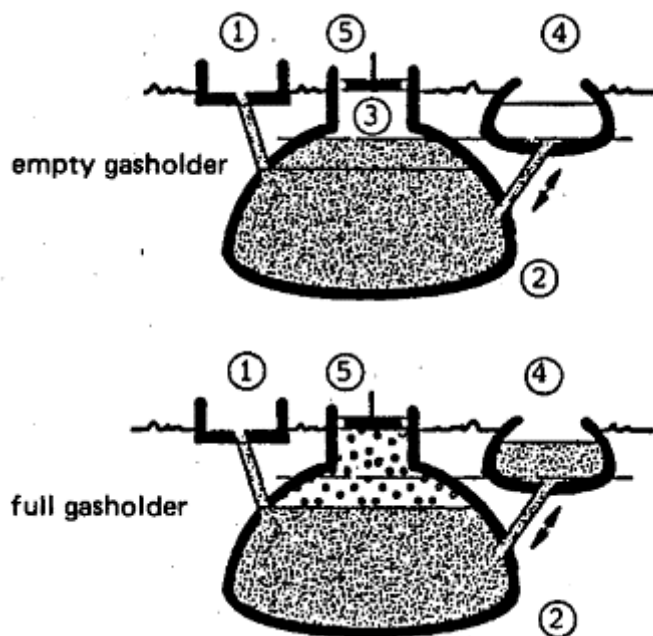


FIGURE 6. Basic function of a fixed-dome biogas plant. 1. Mixing pit. 2. Digester. 3. Gasholder. 4. Displacement pit. 5. Gas pipe /8/

4.1.2 Advantages and disadvantages

Each system has advantages and disadvantages, the same as this fixed-dome plant. The advantages and disadvantages of fixed-dome plant are described in table 7.

TABLE 7. Advantages and disadvantages of fixed-dome plant /8/

Advantages	Disadvantages
Low initial costs	Special sealants and high technical skills
Long useful life-span	Gas leaks occur frequently
No moving or rusting parts	Needed exact planing of levels
Basic design is compact	Plant operation not readily understandable
Construction creates local employment	Excavation can be difficult and expensive in bedrock.

To conclude, this type of plant is recommended only where experienced biogas technicians can maintain, on the other hand, the construction provides opportunities for skilled local employment. Even though the underground construction soften temperature extremes, digester temperatures are

quite low. Nevertheless the underground construction saves space and protects the digester from temperature changes. /7./

4.2 Floating Drum Plants

Floating-drum plants consist of an underground digester and moving gas-holder. The gas-holder moves either directly on a fermentation slurry or in water jacket of its own. Gas drum collects gas and it moves down or rises, depending on the amount of gas stored. Also it is prevented from tilting by a guiding frame. /7./

Floating-drum plants are used for digesting animal and human feces on a continuous feed mode operation. This means that waste or feces should be imputed every day with the same or different amount. Most of the time floating-drum plants are used in farms with a digester size 5-15 m³ or in an institutions and larger farms with a size of digester 20-100 m³/7./.

Water jacket Floating drum plants are easy to maintain and apply. The drum cannot get stuck in a scum layer. This kind of plants are described as a long useful life and more aesthetic appearance. It is recommended to use this type of plant in the fermentation of night soil.

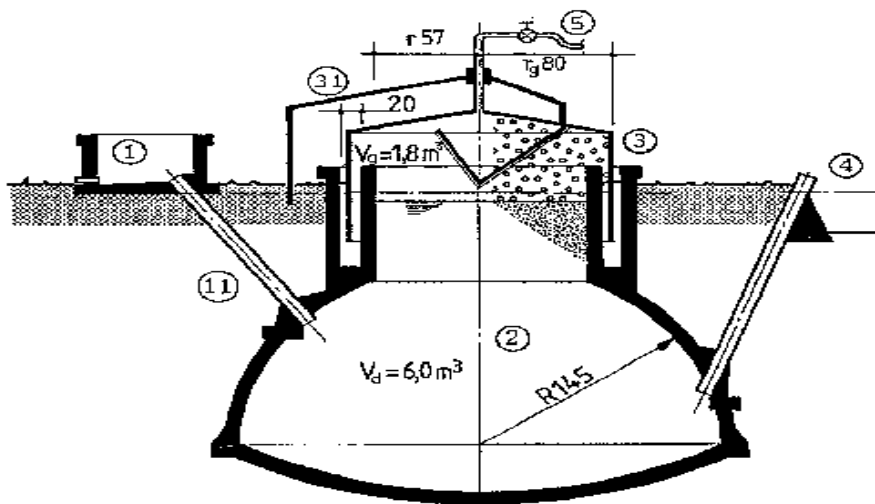


FIGURE 7. Floating drum biogas plant. 1 - Mixing pit. 2 - Digester. 3 - Gasholder. 4 - Slurry store. 5 - Gas pipe. 11 - Fill pipe. 31 - Guide frame. /7./

The digester most of the time is made of brick, concrete or quarry-stone masonry with plaster. The drum must be protected to avoid corrosion and for this at least two preliminary coats and one topcoat should be used. Coatings of used oil are cheap, however, they must be renewed monthly. The gas drum should also have sloping roof to protect rainwater trapping on it, leading to rust damage.

4.2.1 Advantages and disadvantages

Advantages and disadvantages of floating-drum plant are listed in the table 8.

TABLE 8. Advantages and disadvantages of floating-drum plant

Advantages	Disadvantages
Simple, easily understandable operation	High material costs
Gas pressure is constant	Shorter life span
Construction is easy	Regular maintenance costs
	Gas-holder can stuck in floating scum

Floating-drum plants comparing to fixed-dome plants has a shorter life span because of possible appearance of corrosion as it has steel parts. However, when planning floating-drum plant, it is not so important to have experienced biogas technicians, because construction mistakes do not create major problems in operation and gas yield.

4.3 Comparison of various plant designs

When it is necessary to choose the best plant in specific case, various criteria should be considered. In MUAS, there is limited amount of biowaste, biogas plant should also produce required amount of energy. Comparison of various plan designs are described in table 9.

TABLE 9. Comparison of various plant designs /9/

Design:	Floating-drum	Fixed-dome	Water-jacket
Design principle	Continuous-feed, mixed digester	Continuous-feed, mixed digester with slurry store	Continuous-feed, mixed digester
Main components	masonry digester, floating metal gasholder	masonry with displacement pit	masonry digester, floating metal gasholder in sep. water jacket
Preferred substrates	animal excrements, with or without vegetable waste	animal excrements plus vegetable waste	animal excrements with or without vegetable waste
Anticipated useful life	8-12 years	12-20 years	10-15 years
Digester volume (Vd)	6-100 m ³	6-20 m ³	6-100 m ³
Suitability			
advantages	easy construction and operation, uniform gas pressure, mature technology	low cost of construction, long useful life, well-insulated	very reliable, easy construction and operation, uniform gas pressure, long useful life, mature technology
disadvantages	metal gasholder can rust	sealing of gasholder, fluctuating gas pressure	expensive
Operation and maintenance	simple and easy; regular painting of metal gas-holder	easy after careful familiarization	simple and easy; regular painting of metal gas-holder

5 BIOMASS TO BIOPOWER

Before the industrial revolution biomass was mostly burned directly to make a heat. Nowadays from fired heat of biomass stem power are produced and more recently biomass fired steam has been used to generate electricity.

Researchers have found, that there are even more efficient and cleaner ways to use biomass. As it was mentioned before it is possible to convert it into liquid fuels, to produce combustible gases.

Biomass can be produced by combustion, gasification, pyrolysis, extraction and digestion. Biomass conversion processes to energy are described in table 10 /10/.

TABLE 10. Biomass conversion process to energy /10/

Process	Method	Output
Combustion	Thermal conversion	Heat, steam and electricity
Gasification	Thermal conversion	Carbon monoxide and hydrogen
Pyrolysis	Thermal conversion	Liquid, gaseous and solid fraction
AnaerobicDigestion	Biological conversion	Methane

Technology of combustion, gasification and anaerobic digestion are used for energy production from biomass. Heat, electricity and transport fuel can be produced through most of technologies.

Direct Combustion

Direct combustion is the simplest and most common technology to convert biomass to energy. This technology is used for space heating, heating through transfer liquids and steam production for producing electricity or power /11/. This technology is reliable but its efficiency is limited. Typically the thermal efficiency of direct combustion systems are around 20% /12/.

Gasification

Gasification is a part of oxidation process where carbon source is spread into carbon monoxide, hydrogen, carbon dioxide and methane. The temperature and oxidizer used has an affect on the characteristics of the gas. Temperature has a significant effect on level of hydrocarbons for example

in low temperature, such as 700°C -1000° C , the product gas will have bigger level of hydrocarbons than in high temperature (1200 °C -1600 °C). This technology can be used in water heating in central heating, generation of steam for electricity or as part of systems which makes motive force /13/. In addition to this, gasification is more efficient than direct combustion, as gasifying biomass to make electricity is twice efficient and it emits less particulate matter and greenhouse gases /12./

Pyrolysis

Pyrolysis is the process, when biomass is heated in oxygen-free medium to produce gas which is rich in hydrocarbons. Produced gas is immediately cooled, to create a liquid which is similar to oil and sold char, with the proportions depending on parameters of the process. The same as gasification pyrolysis can be in low and high temperatures. The difference between low and high temperatures is that in low temperatures more solid char is produced, and in high temperatures higher proportion of liquid is made. Pyrolysis can be applied in co-firing for heat and power, feedstock for gasification /14/.

5.1 Anaerobic Digestion

Anaerobic digestion (AD) is a treatment technology suitable for wastes or wastewater, containing large amount of organic substances. During the anaerobic digestion, the organic substances in the biomass is transformed into biogas, a mixture of methane, carbon dioxide and nutrient rich sludge. The figure 5 shows that after the anaerobic digestion the produced biogas can be used for power, heat, connected to gas grid or used as a fuel /16./

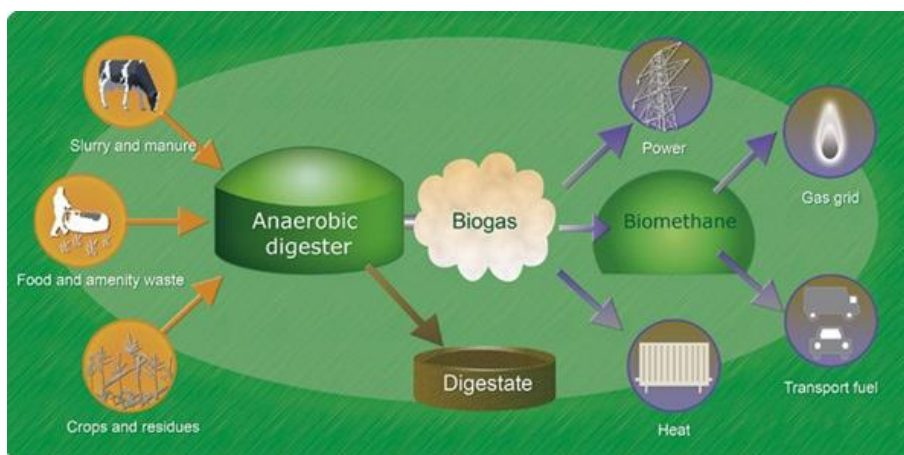


FIGURE 8. Anaerobic digester

Biomass is widely used in AD for production of biogas. The most commonly used substrates are animal manure and slurry, agricultural residues, organic wastes, sewage sludge, energy crops and municipal waste. Municipal waste can be divided in smaller categories, as food waste, paper, glass, plastic etc.

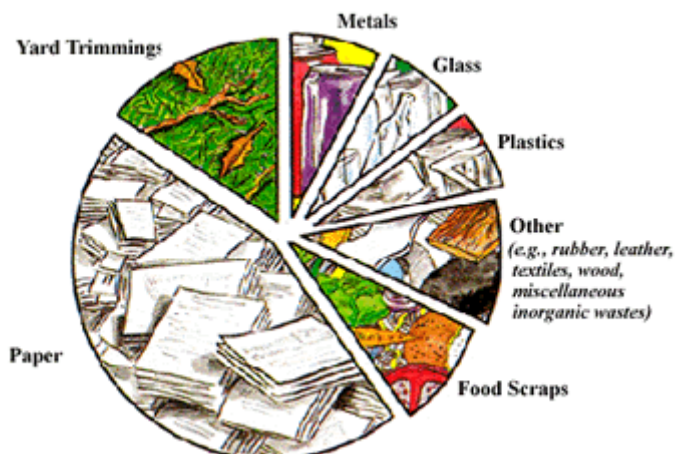


FIGURE 9. Municipal Solid Waste categories /17/

Food waste is one of the most useful feedstock for biogas plants, as it is highly biodegradable and has higher volatile solids destruction rate. Food waste has three times bigger energy potential as biosolids and it is 376m^3 gas/ton, when animal manure has 25m^3 gas/ton and biosolids 120m^3 gas/ton /18/. Due to the limited amount of biowaste and strict amount of energy needed, food waste would be used in biogas plant in MUAS to produce as much energy as possible.

Table 11 shows the different substrates for AD which can be classified according to dry matter content, methane yield and volatile solids. Substrates with dry matter content lower than 20% are used for wet fermentation and substrates with dry matter higher than 35% are used for dry fermentation. From dry matter content depends what type should be used in AD and how much feedstock is needed /15./

TABLE 11. The characteristic of digestible feedstock types /18/

Feedstock	Total solids, %	Volatile solids, % of TS	Methane yield, m^3t^{-1} of TS
Energy crops	30-35	90-98	300-400
Grass/silage	30-35	90-98	260-400
Wheatfeed	85	90-95	320-400
Municipal waste	-	-	400
Animal slurry/sewage	15	70-85	180-200

The most important criteria when comparing different AD substrates is potential methane yield. According to table 11 animal slurry and sewage has rather low methane yield. Because of this animal slurry and sewage is not digested alone, but mixed with other substrates as waste or energy crops, to boost the biogas production. When two different substrates are used in AD it is called co-digestion.

The efficiency of AD depends not only on substrates used, but also on some parameters as temperature, pH-values, volatile fatty acids, ammonia and macro and micronutrients and toxic compounds. The most important parameters in AD are temperature, pH-values and content of total solids (TS).

Temperature

Temperature influences the performance of AD processes and it can take place at different temperatures. There are three temperature ranges: psychrophilic, mesophilic and thermophilic. Temperature has an influence to retention time – the higher is temperature, the shorter the retention time. This relationship between temperature and retention time is shown in table 12.

TABLE 12. Thermal stage and typical retention time /15/

Thermal stage	Process temperatures	Minimum retention time
psychrophilic	<20 °C	70-80 days
mesophilic	30-42 °C	30-40 days
thermophilic	43-55 °C	15-20 days

Most of the modern biogas plants operates in temperatures 45-55°C, because thermophilic process provides more advantages compared to mesophilic and psychrophilic processes. In thermophilic processes is higher grow rate of methanogenic bacteria, retention time is smaller, so process are faster and more efficient. In this process is also better possibility to separate liquid from solid fractions. However, there are some disadvantages in thermophilic process as bigger energy demand due to high temperatures what leads to bigger energy demands and costs /15/.

It is important, that temperature is constant during all digestion process, as the change of temperature has an influence on biogas production. Thermophilic bacteria are sensitive to temperature changes and need more time to adapt to the new temperature, in order to produce the maximum amount of methane production. Mesophilic bacteria is not so sensitive, and temperature difference of +/-3°C do not make reductions in methane production /15/.

pH - values

The pH-value is the measure of a substrate mixture and it is expressed in parts per million (ppm). The pH value has an effect of methanogenic microorganisms growth. pH value inside the digesters depends on pressure of CO₂ and the concentration of alkaline and acid components in the liquid phase. Moreover, the pH-value can be quick, cheap and reliable way to mark system disbalance in systems as AD /15/.

Content of Total Solids (TS)

Digestation process in digesters can operate in high-solids or low-solids processes. High-solids digesters has a total solids content above 20%, when low-solids has TS content less than 20%. Dry processes have the advantage because less space is needed and they have a bigger potential for the processing of municipal organic solid waste.

During the anaerobic digestion several processes are going: hydrolysis, acidogenesis, acetogenesis and methanogenesis, after all these processes biogas is produced and it can be converted to energy.

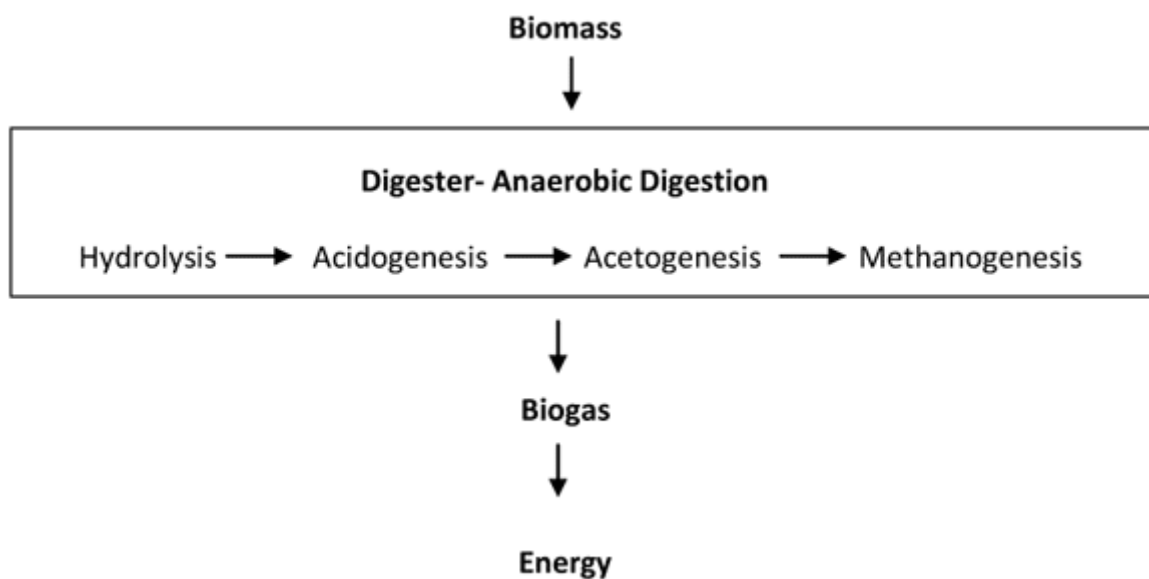


FIGURE 10. Anaerobic digestion fundamental steps /19/

Hydrolysis

Hydrolysis is the main step in anaerobic digestion to separate unusual organic polymers from biomass. During hydrolysis large polymers as proteins, fats and carbohydrates are separated to smaller molecules such as amino acids, fatty acids and sugars. Molecules, which are still large after the hydrolysis should be separated again in the process of acidogenesis, to be useful for methane production /19/.

Acidogenesis

Acidogenesis is the further step of anaerobic digestion in which microorganisms are break down after hydrolysis. These bacteria creates ammonia, shorter volatile fatty acids, carbonic acids, alcohols, water, carbon dioxide. When acidogenic bacteria further breaks down the organic matter, it is still unusable for methane production, so acedogenesis is needed /19/.

Acedogenesis

During the acedogenesis acetate is created from carbon and energy sources by acetogens. Acetogens splits biomass so that it could be used in methanogenesis process to create methane /19/.

Methanogenesis

Methanogenesis is the final process of anaerobic digestion where methane is created. To create methane acetic acid and carbon dioxide is needed. When using acetic acid methane and CO₂ are created and they are two main products of anaerobic digestion /19/.

After all the processes biogas is available to use for further use – heating, electricity or fuels. In order to calculate how much energy it is possible to produce from biogas, energy content should be considered. The energy content of biogas depends to the methane content. To add more, biogas includes about 60% methane and the energy content is ca. 6.0kWh per cubic meter /20/. Other parameters that should be taken into account is total solids (TS), volatile solids (VS), methane yield and energy content of methane. However, these numbers can vary depending of content of wastes used for biogas productions. In my bachelor's thesis the main substrate for biogas plant is food waste from restaurants in MUAS area.

TABLE 13. Parametres of foodwaste /21/

Substrate	TS, %	VS, %	Methane yield, m ³ /kgVS	Cont. Of methane, %	Energy content, MWh/m ³
Foodwaste	40	70	0.4	60	0.006

6 BIOGAS PLANT IN MUAS

6.1 SWOT ANALYSIS

Each system has some advantages and disadvantages. In each project there are also threats and weaknesses that should be managed and benefits create from that. In order to understand and find out the strengths, weaknesses, opportunities and threats of biogas plant in MUAS, SWOT analysis was made.

Strengths

Biogas plant can save an energy and it protects environment from greenhouse effect. When energy produced in own biogas plant, less energy is used from the grid. Also energy made from biogas plant can be used not only for heating, but also for electricity or fuels. To add more, the waste from campus area can be used, there are no additional expenditure for waste removal. If the amount of waste is not enough, agreements with farmers can be made and biogas manure can replace the mineral fertilizer.

Weaknesses

The weaknesses of biogas plant is limited quantity of energy. This problem could appear if not enough waste are used in digestion. Moreover, digestion must meet high standards to be used. If it is installed not paying attention to requirements, the efficiency of plant decreases, and less energy can be produced. To add more, efficiency of biogas plant depends of location proximately.

Opportunities

Biogas plant has a great opportunity to reduce budget for energy. This factor is also the strength of the plant. If there would be enough waste, it would be possible to produce energy for all buildings in MUAS. During the winter time it is possible to use energy for cars pre-heating to avoid freezing. The last opportunity is making additional jobs for qualified workers.

Threats

However, there are several threats that can be met during the process. For example not enough waste for all buildings. If the agreements with farmers are not made, the threat that there are no place to keep used biowaste manure which could replace mineral fertilizers. To add more, if organic waste is not continuously fed or overfed into the biogas plant, it will lead to less or no generation of biogas. The last threat is the possibility that biogas plant will not pay off during several years, if it will not produce enough energy.

7 AMOUNT OF WASTE IN MUAS

In order to find out the answer to the question if it is profitable to build biogas plant in MUAS, the energy consumption and amount of biowaste were needed. The data about energy consumption was collected from each month in 2013. In MUAS there are 19 buildings and the total energy consumption for heating and electricity is shown in table 14.

TABLE 14. Energy consumption of MUAS

Years	District heating, MWh	Electricity, MWh	Water 1000m ³
2013	7364	6447	25

In MUAS there are three main restaurants, Dexi, Talli and Kasarmina. Company RL-Huolinta was collecting biowaste from each of these restaurants from 3 to 4 times in one month, and the total amount of each restaurant is shown in table 15.

TABLE 15. Amount of biowaste by month

Month	Kasarmina Amount, m ³	Dexi, Amount, m ³	Talli, Amount, m ³	All restaurants, Total m ³
January	7,22	3,6	0,72	11,54
February	5,92	3,12	0,72	9,76
March	5,92	2,16	0,48	8,56
April	5,92	2,64	0,72	9,28
May	7,22	3,12	0,72	11,06
June	5,92	2,64	0,72	9,28
July	5,92	1,92	0,72	8,56
August	6,74	2,64	0,24	9,62
September	5,68	3,12	0,48	9,28
October	7,22	2,4	0,72	10,34
November	7,46	4,08	0,96	12,5
December	7,22	3,12	0,48	10,82
Total	78,36	34,56	7,68	120,60

The restaurant Dexi collects the biggest amount of biowaste, and the total amount from whole year is 120.60 m³. The average quantity of biowaste during one month is 10.05 m³. In order to check if it is enough biowaste to produce required amount of energy, parameters of food waste should be considered (table 13) and calculations according to table 13 should be made.

TABLE 16. Amount of energy from wastes from restaurants in MUAS

Amount of waste, kg	120600
Total solids, kg	48240
Volatile solids, kg	33768
Biogas potential, m ³	13507,2
Content of methane, m ³	8104,32
Energy content, MWh	81,04
Real energy content	72,94

Table 16 shows, that from 120600 kg of waste it is possible produce 72.94 MWh. Unfortunately it is not enough for all the buildings in MUAS and the bigger number of waste is needed.

My second aim was to find out what is the best way to use produced energy – use it only for electricity, only for heating or only in one (A – building) for heating and electricity. Energy consumption of (A-building) was calculated according all months in 2012.

TABLE 17. Energy consumption of A – building

Year	District heating, MWh	Electricity, MWh	Water 1000m ³
2012	517	415.35	1.3

District heating and electricity consumptions in A-building is also too big, so it is not enough energy from biogas plant, to use it. However, if the quantity of biowaste would be increased, it is possible to produce enough energy for electricity in A- building.

According to table 13 and table 17 it is possible to calculate in inverse way how much additional waste is needed. After the calculations I found out that in case to produce 420 MWh for electricity 467513 kg of waste is needed.

The last aim was to found out where to get additional 46.7 tons of biowaste if it is not enough waste from restaurants. The great opportunity to get additional waste is make a local agreements with local farmers as they can grow up energy crops which can be used in co-digestion in biogas plant, and remains after the co-digestion can be used as a fertilizer.

8 CONCLUSION

Renewable energy and biomass are becoming more and more popular each year. Before some time, only countries were interested to use renewable energy because of European Union directives, but nowadays renewable energy sources as solar panels, wind turbines and biogases are used in residential apartments too. It is not surprising anymore, when on the top of the roof solar panels are located, when in the yard wind turbine is standing or domestic wastes are used for energy production.

The use of biomass and other renewable sources has a big potential to protect environment, reduce the greenhouse effect and change people mentality and prove, that waste is not the useless material that is thrown away, but also a product for future's green energy. In addition to this, biomass is

flexible and profitable as it can be used not only for heating, ventilation, CHP plants, but also for making fuels and using it as a fertilizer in the land.

I highly believe, that in the future food waste from restaurants will also be used in MUAS area and agreements with local farmers would be made. It would help not only reduce the costs of energy, but also it would be an example for young students to understand that the future can be full of green energy.

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