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PROFITABILITY FACTORS OF BIOGAS PLANTS

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Abstract

Sustainable energy production from renewable sources is important to be able to cut greenhouse gas emissions, decrease the dependence on fossil fuels and ensure a continuous energy supply. Production of biogas is one path to take to achieve this. The objective of this study was to compare Mäkikylä biogas plant's operating model to domestic and international bioenergy plants' approaches to be able to find ways to increase the profitability of biogas plants.

The research method used was qualitative multiple case-study to get an in-depth understanding of different biogas plants functions. Both national and international plants were included in the study. Data collection was done by conducting semi-structured interviews and a questionnaire with Likert scale statements. The data acquired was analyzed by content analysis to find best practices and similarities at the different plants.

The research showed that to increase the profitability of biogas plants the capacity of the plant should be high so that the plant can benefit from economies of scale. In addition, a plant benefit from a two lined plant as different feedstocks can be separated and different digestate products produced which helps in the further use of the digestate as fertilizers. With process optimization, it is possible to increase the gas production amount and gain more of the end product to be sold. A long-term political will encourages the use of biogas and makes investing in the biogas business more attractive.

The plan of the thesis was to compare financial statements of different biogas plants. This was not achieved because of the sensitive nature of the financial information. The interviews and questionnaire conducted gave a good insight into profitability factors that biogas plants should concentrate on increasing their profitability

Keywords

sustainable energy production, biogas plant, profitability, production capacity, feedstock

CONTENTS

1 INTRODUCTION

1.1 Background of the study

Sustainable energy production from renewable energy sources is all the time getting more important. The greenhouse effect is affecting the environment, and decreasing fossil fuel sources are a challenge for continuous energy supply. The decreasing fossil fuel sources are also affecting the price of energy. The European Union has in its 2020 Energy Strategy set a target to reduce greenhouse gas emissions by 20%, increase renewable energy consumption to 20% and to achieve energy savings of 20% by 2020. In addition, all EU countries should achieve a 10% share of renewable energy in their transport sector. (European Commission, n.d.)

The EU Energy Strategy targets show that there is a need to grow both the production and use of renewable energy. Biogas is a renewable energy that is produced in a sustainable way. To increase the production and also use of biogas, the production has to be profitable. The commissioner of the thesis, Kouvolan Vesi Oy, is interested to know what makes a biogas plant profitable. The researcher has previously studied bioprocess engineering and is interested in getting a deeper understanding of the economics involved at plants exploiting bioprocesses. This thesis will focus on comparing the profitability factors at biogas plants owned by Kouvolan Vesi Oy, Gasum Oy and Scandinavian Biogas Fuels AB, to be able to find solutions that could improve the profitability of current and future biogas plants.

1.2 Case company

Kouvolan Vesi Oy takes care of the water supply in the Kouvola area. They produce pure water to their customers, take care of wastewater treatment and run a biogas plant, all in an environmentally sustainable way. This thesis will focus on the profitability of the biogas plant located next to the Mäkikylä wastewater treatment plant in Kouvola.

Building of the Mäkikylä biogas plant started in 2010, and the production was initiated 2011 (Watrec Oy 2015, 3). The ownership of the biogas plant has changed several times during its operation time. In the beginning, the biogas plant was a part of KSS Energia Oy and Kymenlaakson Jäte Oy. The ownership changed 2014 when the City of Kouvola bought the biogas plant. The biogas plant was incorporated to Kouvolan vesi 1.8.2014 to form Kouvolan Vesi Oy. During this time the operation of the biogas plant was outsourced to Watrec Oy. The biogas refining unit was still owned by KSS Energia Oy. (Berner 2015, 3.) In September 2015 the operating of the biogas plant was shifted to Kouvolan Vesi Oy, and in October 2015 also the biogas refining and utilization was transferred to Kouvolan Vesi Oy. (Berner 2016, 3.)

The biogas plant receives wastewater sludge from the wastewater treatment plant and biowaste collected from the nearby community and industries. The received waste is pretreated and after that fermented in a bioreactor. An anaerobic digestion process in the bioreactor degrades the organic material and biogas is produced. The produced biogas consists 65-75% of methane and 25-35% of carbon dioxide. (Watrec Oy 2015, 4-5.)

The produced biogas sold to Gasum Oy and exported to Gasum Oy's natural gas network or it is burnt in the natural gas boiler or transferred into electricity and heat in the CHP -unit. The heat is utilized at the biogas plant as well as at the waste water treatment plant, and the electricity is sold to KSS Energia Oy. The digestate is temporary warehoused by Kymenlaakson Jäte Oy, who also takes care of the further distribution of the digestate. The digestate can be used as field fertilizer or in the production of mold. (Berner 2016, 3-4.)

1.3 Aim, objective and research questions of the study

The aim of this thesis is to improve sustainability of energy production so that more renewable energy resources can be used in energy production. The sustainability in energy production will be approached through the profitability of biogas plants.

The research objective of the study is to compare Kouvolan Vesi Oy's biogas plant's (Mäkikylä biogas plant) operating model to domestic and international bio-energy plants' approaches. The information gained can be used by biogas plants worldwide to improve their operations and make the biogas plant more profitable.

Research work is limited to biogas plants of three companies. Kouvolan Vesi has one plant in Kouvola named Mäkikylä biogas plant, Gasum Oy has seven plants in Finland, and Scandinavian Biogas Fuels AB has three plants in Sweden, one in South Korea and are building one in Norway. The focus will be on the profitability factors of the plants. The comparison of different technical solutions will be left outside of the thesis work.

Regarding Mäkikylä biogas plant's technical solutions, research work has been done by Lehtonen (2012), Heinonen (2014) and Partanen (2010). Lehtonen (2012) focused in her thesis on improving the energy efficiency of the biogas plant and Heinonen (2014) on recycling of the reject water. Partanen (2010) on the other hand focused on the productization of the digestate. The productization affects the profitability of the biogas plant as the digestate can be processed in different ways and sold after that to gain profit. The different productization ways will not be assessed more deeply in this thesis. In her thesis, Nieminen (2015) has done research on biogas plants' profitability. Her work focused more on the investment side and building new plants. Investments will not be discussed in this thesis as the focus is on already existing plants.

To find answers to the research problem the research question of the thesis is: How to increase the profitability of Mäkikylä biogas plant?

Profitability is examined by analyzing costs and income related to:

- Feedstock
- Operation and maintenance
- End products

These three groups are chosen as they cover the biogas production process from start to end. By finding the factors related to each of the groups an understanding of the cost structure of biogas plants will be obtained.

1.4 Research methods

Case study is a research strategy used when answering “how” or “why” questions (Yin 2003, 1). With case study research methodology an in-depth study can be made of a bound entity and when conducting a multiple-case study differences between cases can be explored. (Quinlan 2011, 182; Yin 2003, 50.)

Qualitative multiple-case study is chosen as the research method for this thesis as the study involves three different biogas plants and an in-depth understanding of differences between the plants are searched for. The data collection is done by semi-structured interviews and by reviewing annual reports to get information from different sources. The interviews are analyzed by content analysis and information gathered from other sources are compared and analyzed with the results from the content analysis. Content analysis of the interviews and use of secondary data sources are chosen to achieve reliable and valid research results.

1.5 Framework of the thesis

In the introduction part of this thesis the background of the study, the case company, the research aim, objective and question as well as research methods have been presented. The thesis continues with theory as presented in figure 1 and methodology before the results and analyses part.

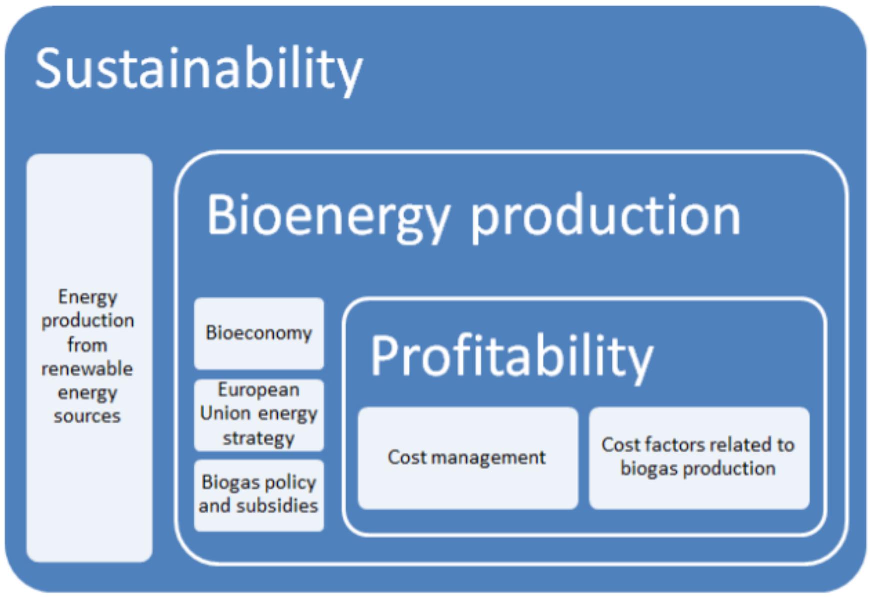


Figure 1. Theoretical framework of the thesis.

The theoretical framework of this thesis shown in figure 1, describes what sustainable energy production is and why it is important. It addresses bioenergy production by introducing the concept of bioeconomy and discussing the current and future situation as well as policies regarding bioenergy production in Europe and Finland. To increase biogas production, it is important that biogas can be produced with profit. Cost management models are researched, and cost factors that are characteristic for biogas production are discussed to be able to analyze the profitability of biogas plants.

Literature review is followed by presentation of the methodological framework used in the thesis. Basics of qualitative multiple-case study research and the research process are presented. In addition, data collection and analysis methods are discussed. After the chapter about methods, the thesis is continued with a presentation of the results together with discussion and analysis of the findings. Finally, conclusion and implications to the commissioner are brought up.

2 SUSTAINABLE AND PROFITABLE BIOGAS PRODUCTION

The literature review presents what sustainable energy production includes and how Europe and Finland are promoting renewable energy production. Also the current state of biogas production in Europe, Finland and Kymenlaakso is discussed. Theory about profitability and cost management models is presented and profitability issues related to biogas plants are discussed.

2.1 Sustainable energy production

Fossil fuels are the main energy source in the world. Fossil fuel resources are all the time decreasing, which affects the energy price. In addition, fossil fuels are responsible for a huge part of all greenhouse gas emissions. The world's dependency of fossil fuels is worrying, and a shift towards sustainable energy solutions are sought for. (Environmental and Energy Study Institute, n.d.)

Biogas is produced by a natural biological process (anaerobic digestion) from renewable organic material. The biowaste used can be waste from agriculture, wood processing, waste management facilities, municipal waste or animal manure, also energy crops are often used, to mention a few. The result of the process is biogas and digestate. The composition of biogas is mostly methane (50-75vol%) and carbon dioxide (25-45vol %). The energy content of the biogas lies in the methane. Biogas can be used to generate heat and electricity. In addition, biogas can be upgraded to bio methane and used as natural gas. (Al Seadi, Rutz, Prassel, Köttner, Finsterwalder, Volk & Janssen 2008, 16-47.)

Production and use of biogas are seen as sustainable practice that can save greenhouse gas emissions. The best-known benefits of biogas are heat and electricity generation and the use of as natural gas, for example, as transportation fuel. In addition, the formed digestate can be utilized as fertilizer. When using the digestate as fertilizer, the use of mineral fertilizers can be decreased. Boulamanti, Maglio, Giuntoli & Agostini (2013) discusses how different practices in biogas production can influence the biogas sustainability. In their work, they identified the two most important factors that influence the biogas sustainability; the choice of feedstock and management of the digestate. Based on their work it should be remembered that even if biogas is regarded as sustainable and the use of biogas reduces greenhouse emissions compared to other energy sources, attention should be put on these factors.

When choosing the feedstock, transportation of the feedstock and in case of some feedstocks also the cultivation of the feedstock should be thought of. These activities require energy and materials, and from a sustainability perspective, the activities should be minimized. In addition, biogas production itself produces some emissions, as well as the utilization of biogas and transportation and disposal of the digestate. Boulamanti et. al (2013) concludes that when electricity is generated from biogas, the impact on the climate change is lower than when electricity is produced by the average European mix that they used as reference in their comparisons. If the feedstock used in biogas production is maize the greenhouse gas savings (savings 35,8%) are lower than if manure is used as feedstock (greenhouse gas savings 332%) compared to the average European mix. The research of Boulamanti et. al (2013) points out that also other environmental factors, for example, ecotoxicity, should be taken into consideration when discussing the sustainability of biogas.

2.2 Bioenergy production in Europe

Bioeconomy includes traditional (agriculture, forestry, fisheries, food, pulp, and paper) as well as emerging industries (bio-chemical, enzymes, biopharmaceuticals, biofuels and bioenergy) that focuses on the production of renewable resources and converting these resources into value-added products. The aim of a bio-based economy is to reduce polluting emissions, increase resource efficiency, prevent loss of biodiversity and find new growth opportunities. Before the industrial revolution economies were based on bio-products, so in that sense bio-based economy is nothing new. Now a transition towards modern bio-based economy is pursued. The challenges modern bioeconomy is facing are the sustainability of the used biomass, efficiency in the use of the biomass and economy of scales when transporting the raw material. (Scarlat, Dallemand, Monforti-Ferrario & Nita 2015, 3-5.)

EurObserv'Er (2015, 126-131) estimates that the European renewable energy source sector had a turnover of €143,6 billion and employed 1,11 million persons in 2014. The biogas sector's share was estimated at € 6,1 million with 66 200 persons employed.

The European Union is dependent on the imported energy, and this has on effect on the economy of the countries. EU countries buy oil from OPEC countries and Russia and gas from Russia, Norway, and Algeria. The cost of the energy rises to above €350 billon/year. As the cost of energy is all the time rising alternative energy sources are sought for. The aim is to secure Europe's energy supplies, take care that rising energy prices do not make Europe less competitive, decrease greenhouse gas emissions and protect the environment. (European Commission 2012.)

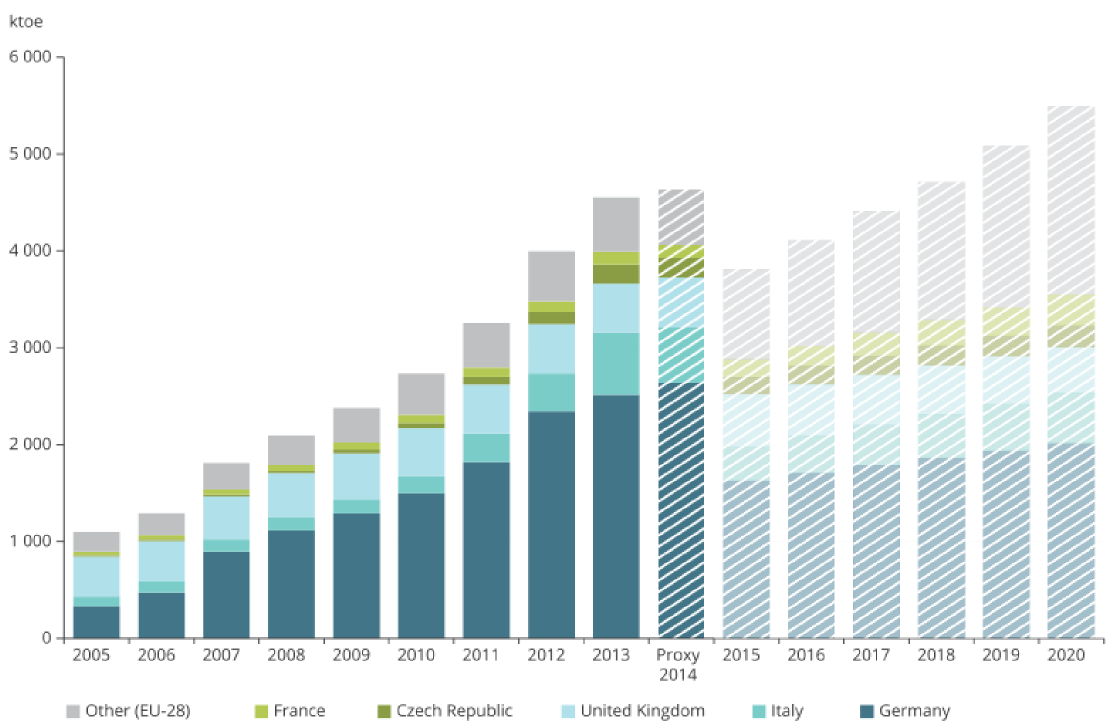
The European Union has made energy strategies for 2020, 2030 and 2050. The European Commission (n.d.) have set the following targets of the energy strategies for 2020 and 2030:

- To reduce greenhouse gas emissions by 20% by 2020 and by 40% by 2030 compared to the level of 1990.
- To increase of renewable energy use to 20% of total energy consumption by 2020 and 27% by 2030.
- To improve energy efficiency by 20% by 2020 and 27% by 2030.
- By 2030 15% electricity interconnection between EU countries (electricity generated in the EU can be transported to other EU countries)

The energy strategy for 2050 aims at cutting the greenhouse gas emission by 80-95% compared with 1990 levels. (European Commission, n.d.)

Progress has been made to meet the targets. Between 1990 and 2012 18% of greenhouse gas emissions have been cut, and renewable energy consumption increased to 15,3% in 2014 from 8,5% in 2005. The energy efficiency target is predicted to end at 18-19%, which is a bit less than the target. (European Commission, n.d..)

Biogas production has increased by 11,9% between 2012-2013 (EurObserv'ER 2014, 45), 6,6% between 2013-2014 (EurObserv'ER 2015, 43) and between 2005-2013 the growth rate has been 19% (European Environment Agency 2016, 32). As seen in figure 2, Germany and Italy are the main producers of biogas from anaerobic digesters. The United Kingdom is also a big producer of biogas. In the UK most of this biogas comes from landfills where the biogas is collected directly from inside the landfills. Thus the biogas is not industrially produced. (EurObserv'Er 2014, 45-47.)



Notes: This figure shows the realised final renewable energy consumption for 2005–2013, approximated estimates for 2014 and the expected realisations in the energy efficiency scenario of the NREAPs for 2015–2020.

Source: EEA (based on data from Eurostat and NREAP reports).

Figure 2. Electricity generation (ktoe) from biogas in EU member countries (European Environment Agency 2016, 32).

Due to biogas policy changes in Germany (withdrawal of premium for using energy crops) and Italy (decrease of feed-in-tariffs), the biogas production is estimated to decrease 2015, as displayed in figure 2. (EurObserv'Er 2015, 44-47.) European Biogas Association (2015) reported 17 240 biogas plants in Europe at the end of 2014, which shows an 18% growth compared to 2013. Of these plants 83, are situated in Finland. Biogas upgrading units were reported to be 367 of which 9 in Finland.

One of the biggest challenges biogas production is facing is the availability and competition of biomass. Even if biomass is a renewable resource, its availability is limited, and the production of the biomass requires land and other resources like water and nutrients. In addition, when a comprehensive transition towards a bioeconomy has occurred, the competition of available biomass will become acuter. Biomass will be needed not only to produce energy but also for biomaterials and chemicals. When considering EU countries, it is expected that they will need to relay on imported biomass. (Scarlat et al. 2015, 26-27.) A concern regarded biomass production is that land area suitable for cultivation of food will be used for the cultivation of energy crops for energy production. The European Commission is trying to intervene in this, and they are insisting that biogas production should be based on byproducts and organic waste to limit the use of energy crops. The biogas sector is waiting to see how the EU legislation will affect biomass availability as this will affect the growth potential. Even if the legislation limits the use of energy crops, the legislation regarding collection and use of different types of organic waste will most probably bring new fermentable waste streams to replace the decreased use of energy crops. As these decisions are made on the EU level, the future development of the biogas sector is a political issue. (EurObsev'ER 2015, 48-49.)

Some of the opportunities that lie in a future bio-economy are biorefineries and development of rural and industrial areas, in addition to the already discussed sustainable use of resources and decrease of greenhouse gas emissions. Biorefineries are plants that produce both value-added products (bio-materials, bio-chemicals, bio-plastics, food, feed) and bioenergy at the same site. At these plants the waste streams from production of the value-added products can be used in energy production. These kinds of solutions are already exploited in the pulp and paper industry. The need of more biomass and non-food market of biomass will affect the development of rural areas as these opportunities can provide new and alternative income sources for farmers. (Scarlat et al. 2015, 28-29.)

McCormick and Kåberg (2007, 443) found out in their study the main barriers to the expansion of bioenergy in Europe to be economic conditions, know-how and institutional capacity and supply chain co-ordination. They state that the barriers are relating to non-technical issues rather than technical.

The economic conditions are related to subsidies that are paid for energy production. Fossil fuels and nuclear power compete in the energy market with renewable energy sources. One could assume that only the renewable energy sources would be receiving subsidies, but rather surprisingly also nuclear and fossil energy is receiving them in some cases. For energy from renewable energy source to be profitable subsidies are needed. McCormick and Kåberg (2007, 449) state that external costs (negative and positive impacts) should be internalized in energy markets. In addition, when establishing new bioenergy plants investment grants play an important role. (McCormick & Kåberg 2007, 448-449.)

Biogas is one form of bioenergy. In Finland biogas is produced at co-digestion plants, sewage plants, by landfill collection and at farms. In 2015 altogether 152,9 million m^3 biogas was produced. This was a 1,5% decrease compared to 2014, but at the same time, the usage percentage rise to 86% (2015) from 84,5% (2014). Landfill collection produces the biggest amount of biogas, 83,3 million m^3 in 2015, although this is an 11% decrease compare to 2014. Biogas from other sources has been growing and in 2015 bioreactor plants (co-digestion, sewage plants, and farms) produced 69,6 million m^3, which is a 12% rise compared to 2014. The trend shows that the production capacity of bioreactor plants is growing. From the available biogas, heat was produced 483,4 GWh and electricity 147 GWh. The transportation sector used 4% of the produced biogas. The amount of energy produced corresponds to approximately 0,5% of all renewable energy produced in Finland. (Huttunen & Kuittinen 2016, 13, 16-17.)

According to the Biogas plant register made by Huttunen & Kuittinen (2016, 29-32), the number of co-digestion plants in Finland is 14, and 23 more are under construction or in the planning phase. A visit (20 October 2016) to the webpages of the biogas plants shows that of these 23 plants 8 are already in operation and it can be concluded that the biogas production amount in 2016 is higher than the amounts in 2015 reported by Huttunen & Kuittinen (2016). According to Huttunen & Kuittinen (2016, 29), the co-digestion plants process biowaste, manure and sewage sludge. The oldest plant was built in 1990 and is one of the world's first co-digestion plants. In 2015 225 000 ton of sewage sludge and 180 000 ton of biowaste was processed at the co-digestion plants. The biggest co-digestion plant is situated in Lahti (Labio Oy) and produced 7390 000 m^3 of biogas 2015.

Biogas is supported in Finland by investment and production grants as well as by means of taxation. The support actions are driven by Finnish political objectives that are based on the European Union's renewable energy directive. The Finnish political targets are: to sustainably grow the use of renewable energy so that in the 2020s the usage percentage is over 50% and self-sufficiency rate is over 55%, to grow the share of biofuels in transportation use to 40% until 2030 and encourage the public sector carbon neutral solutions. Bioeconomy and clean solutions are spearhead projects for the government. According to the government strategy 2015, investments of 300 million euros will be made to these sectors. (Mutikainen, Sormunen, Paavola, Haikonen & Väisänen 2016, 8, 24.)

For renewable energy production facilities investment grant of up to 30-40% can be received depending on the technology that is planned to be used. A second support system is the biogas electricity feed-in tariff system that came into force at the beginning of 2011. To receive the feed-in-tariff the generator power at the plant needs to be at least 100kVA. In addition, only new plants can get involved in the system and plants that have received the investment grant or some other support from the state cannot receive the feed-in-tariff. Feed-in-tariff support is paid as the difference between the target price (83,50 €/MWh) and a calculated three months average market price. Heat generation at the same CHP-plant gives the right to receive a heat premium of 50 €/MWh if the efficiency ratio exceeds 50% at 1 MVA generators and 75% at generators over 1 MVA. A biogas electricity producer that is not eligible to receive feed-in-tariff can receive a production support that is 4,2 €/MWh. The taxation reliefs are directed towards the traffic sector. Normal traffic taxation in Finland includes car tax, road tax, and fuel/excise tax. For fuel, there is in addition surtax, stockpile fee, and VAT. Biogas is exempt from fuel/excise tax, surtax, and stockpile fee. (Mutikainen et. al 2016, 24-25.)

For the continuous development of biogas business in Finland, it will be important to improve the competitiveness and increase the demand of end-products of the biogas production process. According to Mutikainen et. al (2016, 22, 81), one factor that will contribute to this is to increase the knowledge generally about the potentials of biogas production as well as the availability and benefits of the products. In addition, the availability of enough biomass is crucial for the growth of biogas production. The government act related to landfills has been reviewed 2013, and according to the new legislation (331/2013), most of the biodegradable and organic waste cannot be placed in landfills after 2016. Landfills will not accept organic waste that has a total organic content (TOC) or volatile suspended solids (VSS) >10 %. This will increase the amount of biomass that needs to be treated by other means.

In Kymenlaakso region Kymenlaakson liitto has been the driver in creating a Natural Resource Strategy for the area. The strategy is done for the period of 2011-2020, and it aims at creating practices for sustainable use of natural resources and developing a bioeconomy that relies on regional strengths. The vision of the region is to be a pioneer in sustainable, efficient and innovative use of natural resources. The development priorities are defined to be: bioeconomy, sustainability, circular economy, regional resources, international interaction as well as know-how and communication. (Kymenlaakson liitto 2011, 2, 5-9.)

Regarding a future bioeconomy, wood, wind and other rapidly renewable natural resources are the strengths of Kymenlaakso region. At the international comparison level Kymenlaakso region is a major consumer of natural resources and energy. Wood and pulp industry is a big actor in the region and as the forest sector is evolving, the target is to develop new and energy efficient production structures alongside the traditional forest industry. To improve the energy efficiency is one of the key targets. To promote energy production, the focus is on sustainable use of forest products, development of wind power and exploitation of agricultural bioenergy and sewage sludge. The aim is to reach a high degree of self-sufficiency. (Kymenlaakson liitto 2011, 6.)

Biogas production is one factor that can influence in reaching the targets set by Kymenlaakso region's Natural resource strategy. Biogas is produced in Kymenlaakso at two biogas plants. Mäkikylä biogas plant is situated in Kouvola and has been in use since 2011. The plant can process 19 000 ton biodegrade waste and produces approximately 14 000 MWh biogas yearly. (Kouvolan Vesi Oy, n.d.) The second biogas plant is Virolahti biogas plant situated in Hamina that was taken in use at the beginning of 2016. Virolahti biogas plant can process 19 500 ton biomass, and an enlargement is planned so that altogether 36 000 ton could be processed yearly. The Virolahti biogas plant produces 15 000 – 20 000 MWh biogas yearly. (BioGTS n.d., Haminan Energia Oy n.d..)

2.3 Profitability factors

Profitability is the ability of a business to obtain profit from its economic activity. Profit is achieved when income is bigger than expenses. When making economic decisions, the option with the highest profitability is usually chosen. (Geamanu 2011, 116-118.) Several factors have an impact on business's profitability, and it is important to be able to understand and predict these factors. Several cost management models have been created to offer structured ways to analyze the factors. The models created are quite specific as well as complex, and choice of the model depends on what challenges, decisions or environments ought to be evaluated and from what perspective. Examples of profitability models are activity-based costing (ABC), total cost of ownership (TCO) and supply chain costing (SCC). Challenges connected to the models are what costs to include and, how to measure the costs. (Ellström, Rehme, Björklund, & Aronsson 2012, 1066-1068.)

The ABC-model is seen as a starting point of many other cost management models and focuses on costs related to products, services or departments depending on what is under evaluation. (Ellström et. al 2012, 1066-1071.) In the ABC-model activities related to the production of a product or service are divided into a hierarchy of four levels: unit-level, batch-level, product-sustaining and facility-sustaining. The unit-level includes activities done in proportion to the produced volume. The batch-level costs are related to every batch and do not change depending on the batch size. Product-sustaining activity costs support the product portfolio and facility-sustaining activity costs are needed to maintain the production facility. The model aims at considering the relevant costs in the cost analysis. (Ittner, Larcker & Randall 1997, 144-145.) Ittner et al. (1997, 145-146) state that one challenge related to the ABC-model is that even if the ABC-model says that the different levels are independent, the model does not take into consideration how total number of products, batches, and units relates to each other and the total cost.

Other models have evolved from the ABC-model to take different perspectives better into focus. The SCC-model has been created to better take into consideration the supply chain perspective and costs related to multiple firms along the supply chain. The SCC –model includes transaction costs, information costs, physical flow costs and inventory carrying. (Ellström et. al 2012, 1070.) The TCO model is developed for supplier selection and evaluation in purchasing. It aims at analyzing true costs of any activity and not only the costs allocated or paid externally. The purchasing activities taken into consideration in the TCO-model are activities related to management, delivery, service, communication, quality, and price. By taking all the costs into consideration, the TCO-model can provide information that helps in reducing the total cost of purchasing an item. For example, when taking all the activities and costs related to the activities into consideration of placing an order or following up a problem, indirect costs and differences between suppliers can be noted that cannot be seen in only the price paid. (Ellram & Siferd 1993, 164-170.)

Cost management models give a good understanding of different factors that should be considered when assessing the profitability of businesses. But as stated above, the models are quite specific and created from specific perspectives. In addition to the profitability factors included in the cost management models, there are other factors to consider, such as industry specific factors and organizational factors. Hansen & Wernefelt (1989, 400) write that business's profitability is affected by characteristics of the industry, the business's position relative to its competitors and the quality or quantity of its resources. Industry variables are growth, concentration, capital intensity and advertising intensity. The most important variable related to competition is relative market share. In addition to these variables, also firm size can have an effect on the profitability. Hansen & Wernerfelt (1989, 401) also discuss organizational factors that can affect the performance of the business and thus the profitability. These factors are related to managers and how they can influence the behavior of their employees by formal and informal structure, planning, reward, control and information systems, employee skills and personalities and how these all relate to the environment. The organizational factors are hard to measure, which makes it hard to assess how they affect the profitability.

In addition to manger-employee interaction, also manager-stakeholder interactions can have an effect on business profitability. Halal (2000, 10-12) discusses in his article how building up a corporate community where a business includes stakeholders into collaborative problem solving can increase the businesses profitability. He notes that while capital is a limited resource, the value of knowledge increases when shared. Knowledge can easily be transferred, and it cannot be used up. For these reasons, a collaborative partnership between stakeholders can be economically productive and improve business profitability.

A cost management model that would be applicable as such to assess the profitability of biogas plants was not found in the literature. The general cost management models give a good understanding of factors that affect business profitability in general. Literature was further researched to understand factors that specifically affect biogas plants profitability. The focus was chosen to be on costs and income sources. Organizational factors and impact of stakeholder interaction were left outside the scope of this review.

Profitability of a biogas plant is affected by several factors. The costs and income sources can roughly be divided into three parts; feedstock/biomass, operation of the plant and end products. The influencing factors are outlined in table 1, and they will be discussed closer below.

Table 1. Factors influencing the profitability of a biogas plant (Blokhina et al. 2011, 2089-2090; Delzeit & Kellner 2013, 46; Gebrezgabher et al. 2010, 111; Igliński et al. 2012, 4894; Gebrezgabher et al. 2010, 111; Stürmer et al. 2011, 1559).

FEEDSTOCK	OPERATING AND MAINTENANCE	END PRODUCTS
Supply cost	of feedstock handling system	Electricity sale
Gate fees (waste disposal fees)	of digester	Heat sale
Plant capacity	of CHP unit	Sale of energy certificates
Transport distances of feedstock	Labour costs	Subsidies
Type, availability and yield	Taxes	Sale of digestate
	Incurance	Storing of digestate
	Utility costs	Disposal of digestate
	Biogas upgrading cost	Disposal of process water

Different feedstocks can be used for biogas production and the economic factors outlined in table 1 under the feedstock category depend on the used feedstock. The feedstock used most often depends on feedstock availability and in this way also plant location, and regional differences play an important role in biogas production. Feedstock composition affects the methane yield (Gebrezgabher, Meuwissen, Prins, & Lansink 2010, 111) and often different feedstock are digested together to improve the properties of digestion mix and achieve a higher yield (Palm 2010, 20). The cost of the feedstock increases the longer the transport distances get and for that reason it is crucial for the profitability of the biogas plant to use feedstock that can be retrieved from a close distance (Blokhina, Prochnow, Plöchl, Luckhaus & Heiermann 2011. 2089; Rajendran, Kankanala, Martinsson & Taherzadeh 2014, 89; Gebrezgabher, Meuwissen, Prins & Lansink 2010, 112; Stürmer, Schmid & Eder 2011, 1552-1553; Delzeit & Kellner 2013, 43). According to Gebrezgabher et al. (2010, 112) a maximum distance for feedstock and digestate transportation that is viable is 15-25 km, while Puksec & Duic (2012, 432-433) define in their research that farms delivering manure to a centralized biogas plant in Croatia should be located at a maximum of 10km distance from the biogas plant.

The price of the feedstock depends on the used feedstock and the agreements the biogas plant has with the feedstock suppliers. In some cases the biogas plant pays for the feedstock delivered to them, the feedstock might be borrowed to the biogas plant for free in exchange for digestate that can be used as fertilizers and, for example, in case of waste a compensation/gate fee is paid to the biogas plant for the service to handle the waste. (Puksec & Duic 2012, 428-429; Palm 2010, 5-6.) Palm (2010, 8-9, 17-18) points out that gate fees can vary between suppliers depending on contracts made and the details are often seen as business secrets. Competition of feedstock is also all the time growing which will have an effect on availability and price of feedstock in the future.

When the used feedstock is of animal origin hygienisation is required as a pre-treatment. Hygienisation is done prior to digestion, and if feedstock of animal origin is mixed with other feedstock, all of the feedstock is hygienised. Hygienistation brings additional costs to the biogas plant and should be considered when analyzing the profitability of a biogas plant. The biggest waste source from agriculture is manure that requires hygienisation. In addition, slaughterhouse waste is a sought-after feedstock by biogas plants. It is recommendable for biogas plants to use a variety of different feedstocks as this brings security in the supply of feedstock when the plant is not dependent on just a few suppliers. (Palm 2010, 5-7, 21.)

There are different size and types of biogas plants, ranging from small anaerobic digesters to large co-digestion plants. The size of biogas plant plays a role as a bigger plant requires more feedstock, which often leads to a bigger collection area, longer transportation distances and finally higher feedstock costs. At the same time, a big plant can benefit from economies of scale in production costs and energy efficiency of CHP unit. (Stürmer et al. 2011, 1558; Delzeit & Kellner 2013, 45.) Rajendran et al. (2014, 88) showed that doubling a plant's capacity was less capital intensive compared with a plant of lower capacity. But on the other hand doubling the feedstock processing capacity did not double the biogas productivity, as the biogas productivity was increased by 82,7%. To compare total feedstock costs of biogas plants with different sizes Stürmer et al. (2011, 1553) suggests using feedstock cost per produced unit of methane or feedstock cost per produced unit of electricity.

Rajendran et al. (2014, 88-90) discusses that in some cases a biogas plant can benefit from having two smaller digesters instead of one big. If the supply of enough feedstock is an issue and a plant with one large digester sometimes needs to run the plant at reduced capacity, the imbalance of the loading can have an effect on the stability and efficiency of the process and recovery of the process may take time. Having two digesters is capital intensive, but if feedstock supply is limited the plant can still run one digester at full capacity while stopping the other and in this way maintain the stability of the process and benefit from the more capital intensive option of having two digesters.

The end products of anaerobic digestion are biogas and digestate. The biogas can further be upgraded to correspond to natural gas or converted into electricity and heat. As a big share of the end product comprises of digestate, it is important to maximize the profit from it as well as from the biogas and electricity generated. It is also good to be aware that a high share of manure input increases the amount of digestate as the energy content in manure is low. (Gebrezgabher et al. 2010, 111; Delzeit & Kellner 2013, 43-44.)

Subsidies paid for the production of renewable energy are a crucial factor influencing the profitability of biogas plants. Several researches have concluded that in the current energy situation and as long as renewable energy competes with the price of fossil fuel, subsidies and/or other regulations are needed to make biogas production in large quantities profitable. (Bojnec & Papler 2013, 79-80; Palm 2010, 23-24; Gebrezgabher et al. 2010, 113; Stürmer et al. 2011, 1559; Delzeit & Kellner 2013, 43.) Subsidy means that are in use in Europe depending on the country are tax supports, direct supports, certification systems, funding with low-interest rate, supports for development of small and medium-sized enterprises, low tax rates for electricity from renewable sources of energy, investment and other loans at low-interest rates with government guarantees, guaranteed prices, feed-in tariffs for electricity and long-term contracts. (Bojnec & Papler 2013, 79-80; Igliński, Buczkowski, Iglińska, Cichosz, Piechota & Kujawski 2012, 4894; Stürmer et al. 2011, 1559.)

When analyzing the profitability of a biogas plant, there are several factors that are hard measure. The intangible factors should be kept in mind when making economic decisions. The location of the plant cannot be measured in money but is has on effect on feedstock supply and price. It is important to ensure stable availability of feedstock to avoid instability in the production process (Bojnec & Papler 2013, 77). Also if the location is near to potential energy customer, this reduces the network loss of sent energy (Igliński et al. 2012, 4895).

3 METHODOLOGY

Qualitative Multiple-case study is chosen as the methodology for this research. The primary data is collected by semi-structured interviews, and secondary data is collected mainly from annual reports. To analyze the data content analysis is conducted. This chapter describes the chosen methods more closely.

3.1 Qualitative Multiple-case study

Case study research methodology is chosen as it is a method with which to do an in-depth study of a certain situation or bounded entity (Quinlan 2011, 182; Metsämuuronen 2006, 90-92). A case study can be described as a study that researches in a current situation and pursues to understand the case in depth. A case study searches for similarities and also what is different and unique in the particular case. In a case study, the idea is to understand the particular case instead of generalizing it. In a case study, the researched phenomenon is described by using different data sources. (Metsämuuronen 2006, 90-92.) Using different data sources is known as triangulation. If several data sources give similar results, the results can be seen as confirming each other. If they differ, the underlying reasons have to be studied more closely. (Gillham 2012, 13, 29-30.)

According to Yin (2003, 46-55) case studies can be divided into different types. In this research, a multiple-case study will be conducted. In a multiple-case study differences between cases are explored, and comparisons are sought for.

A multiple-case study fits well with the objective of the thesis to compare the operating models of several biogas plants. Plants are compared to each other and differences/similarities in their costs and income sources are explored. An in-depth study is made to get a versatile understanding of the biogas plants' profitability. The focus is to answer a "how" -research question, which confirms the selection of exploratory case study as the method (Ellram 1996, 97-98).

The study is qualitative in nature as the aim is to express results verbally when trying to understand how different factors influence the profitability of biogas plants. (Ellram 1996, 95-97.)

3.2 Research process

Yin (2003, 21-28) suggests a five step research design for conducting a case study:

1. a study's question
2. its propositions, if any
3. its units of analysis
4. the logic linking the data to the propositions
5. the criteria for interpreting the findings

The research process of this thesis starts with defining the case; its aim, research objective, and question. Defining the case is important as it clarifies the boundaries and what is of interest when conducting the research. The next step is to create a theoretical framework to see what knowledge there is already in the area and to get a deeper understanding of factors and drivers affecting biogas production.

Step two in Yin’s (2003, 22) research design protocol is to define the propositions of the study. The propositions guide the study by giving a focus for the data collection and analysis. In this thesis, propositions are derived from the information collected in the literature review regarding factors affecting the profitability of a biogas plant. The data collection will concentrate on gathering information about these factors and the interview questions are built based on them.

The research process continues with defining the units of analysis (Yin 2003, 22-26) that in this study are biogas plants. For the research of this thesis, several plants are needed as the aim is to compare the biogas plants to each other. The number of biogas plants is limited as it is a challenge to get access to the in-depth information about income and cost factors that are needed for the research. The biogas plants participating in the research are Mäkikylä biogas plant in Kouvola, Gasum’s biogas plants in Finland and Scandinavian Biogas Fuels AB’s biogas plants in Sweden and South Korea. When defining the unit of analysis also time boundaries are determined. In this thesis, the time period that is reviewed regarding incomes and costs is the year 2015 as that is the previous full year that can be researched at the time of conducting this study.

The data collection is done by interviews and by reviewing annual reports and financial statements. First, a pilot study is conducted at Mäkikylä biogas plant. The aim of the pilot study is to test the case study design. After the pilot study it is possible to refine the interview questions and other data collection techniques if needed (Ellram 196, 118). The research then continues by collecting data from the other biogas plants participating in the multiple-case study.

The final step is analyzing the results. In addition to analyzing, the results are interpreted and explained. Conclusions of the research are finally made. (Yin 2003, 26-28.)

3.3 Data collection

The primary data will be collected by interviewing. Secondary data will be collected from annual reports and other archive documents available at the target plants. Semi-structured interviews will be made face-to-face, by skype or if the previous are not possible telephone interview will be done. Face-to-face interviews are chosen as the aim is to collect sensitive data and face-to-face interviews give a possibility to a rich communication when questions are open-ended. The interviews will be recorded for analysis. (Gillham 2012, 62, 65.)

A semi-structured interview is both flexible and standardized. Open-ended questions are used to be able to receive as versatile answers as possible and to give the interviewees a freer atmosphere to give own opinions. The researcher needs to listen what the interviewee has to tell and also ask clarifying questions when needed. It is important for the researcher to ensure that the conversation keeps on track so that all the interviews made have similar coverage over the topic. This is important when analyzing the results. (Gillham 2012, 67-69.)

The interview questions are formed so that the questions focus on the profitability factors of a biogas plant. At the end of the interview, the interviewee will be asked to answer a few questions on a Likert scale related to how they perceive the importance of the profitability factors now and how they think the situation will be different after 5 years. The Likert scale used will be a five-level scale going from 1, most important factor, to 5, not important at all. The interview questions are presented in attachment 1 and the questionnaire with the Likert scale statements in attachment 2. (Allen & Seaman, 2007.)

The recorded interviews will be transcribed as soon as possible after the interviews have been done. Gillham (2012, 71) points out that fast transcription is recommendable as the researcher’s memory will help in the transcription process. Partial transcription will be conducted, and only information seen as relevant by the researcher will be written down. Full transcription would be too onerous to be made in the time that is on hand for making this case study. (Powers 2005, 25.)

3.4 Analysis of data

There are several approaches to qualitative data analysis, and many of them have the same steps: starting with transcribing, going on to reading and generating categories, themes and patterns and finally interpreting data and writing report. For the purpose of this thesis, content analysis is chosen as the analysis method. A deductive approach is taken, and the categories for content analysis are formulated based on the theory of the literature review before starting with the actual data analysis. During data analysis the categories may be revised if needed. (Wilson 2010, 254-255.)

Gillham (2012, 71-75) describes the steps of content analysis to involve 11 steps after the transcribing is done. The idea is to take one transcript at a time and highlight substantive statements, with other words those statements that are meaningful. In case repetition is noticed, the similarities should be highlighted only once unless there can be seen some new information in the repetitive statement. When all the transcripts are done, the researcher should go through them again to make sure nothing has been missed or are there same statements that are highlighted during the first round that is not meaningful after all. The following step is categorizing. If the categories are not formed before analyzing they should be created now. If a deductive approach is chosen, as described by Kohlbacher (2006) and Wilson (2010, 255), the categories have already been formed. The highlighted statements are then coded by assigning a category to them. After coding, the researcher makes a summary of the coded content. It can be done on a grid, where the categories are written vertically on top and the respondents horizontally on the side. In the cells, each respondent’s statements regarding the categories are marked. There will probably be some statements that do not fit into any category. These statements should not be forgotten but be marked as unclassified statements. The statements that have been put into the grid should be marked in the transcript, in this way it is possible to keep on track with what have already been processed. After all the transcripts have been coded, the researcher interprets the results and writes the report.

In this research categories are created based on theory in chapter 2.3.1., the factors displayed in table 1 are used as a starting point of the content analysis. The content analysis grid is shown in attachment 3. The results of the content analysis will be analyzed with the information gathered from the secondary data to find similarities and differences between the biogas plants. The aim is to analyze how the plants achieve their profit and to find out what improvements could be done at Mäkikylä biogas plant to improve their profitability.

3.5 Reliability and validity

The quality of a research is built up of research reliability and validity. Reliability is related to the operations of the study and that the study can be repeated with the same results if needed. To conduct a reliable case study, the researcher should have a case study protocol and collect the material to a database that can be accessed in the future. When documenting the research, a good rule to keep in mind is that the research should be document so well that the study procedures can be made again based on the documentation and the same results can be obtained. (Yin 2003, 34-39; Wilson 2010, 116-117.)

Validity can be divided into construct validity, internal validity, and external validity. Construct validity is reached through triangulation, using multiple sources of evidence (see chapter 3.1) and also chain of evidence is used. The principle of chain of evidence is to let the reader be able to follow all the steps closely in the case study report from start to conclusion or from the conclusion to start; either way, should work. Internal validity is related to the analyzing techniques that proper technique is chosen and used depending on the characteristics of the case study. Finally, external validity is about how the study is generalizable to similar cases. A case study relies on analytical generalization and testing by replication. In single-case studies, the researcher should use theory to improve external validity, and in multiple-case studies, Yin (2003, 34) recommends replication logic. (Yin 2003, 34-37, 105-106.)

In this thesis to achieve reliability and validity the interviews and the content analysis are made based on case study protocol and the material gained is collected to one place. In addition, the aim of the researcher is to write the cases study report so that it is easy for the reader to follow all the steps made according to the principle of chain of evidence. Multiple sources of evidence are used, interviews, annual reports, and other archive documents. Content analysis is chosen as an analyzing technique and as a multiple-case study is conducted both internal and external validity are taken into consideration.

4 RESULTS AND ANALYSIS

4.1 Stakeholders participating in the research

The aim of this case study was to collect data from the participating companies from different sources. Unfortunately, economic data and exact figures are of such a sensitive nature that only the commissioner of the thesis, Mäkikylä biogas plant, was able to give all of the asked data. The other participating companies could not give out the data even if the numbers had been coded. As Scandinavian Biogas is a listed company in Sweden, they have their annual report with financial data available on their website, but as the numbers cover the whole company, it is not detailed enough for the purpose of this research. Nonetheless, all the asked companies were more than willing to participate in this research and give in-depth interviews as well as answered the questionnaire about the importance of different factors.

From Mäkikylä biogas plant the plant manager participated in the research. Mäkikylä biogas plant is located in Kouvola. The biogas plant is situated next to the waste water treatment plant of Kouvolan Vesi Oy.

Gasum Oy owns seven biogas plants in Finland located in Vampula, Honkajoki, Kuopio, Oulu, Riihimäki, Turku and Vinkkilä. In addition, Gasum cooperates with biogas plants in Kouvola (Mäkikylä), Espoo and Lahti. At the beginning of 2017, Gasum Oy bought Swedish Biogas International and through the acquisition, the ownership of five biogas plants in Sweden was transferred to Gasum. The acquisition made Gasum the biggest biogas producer in the Nordic countries. (Gasum Oy, 2017). From Gasum the biogas production director with a production planner was interviewed for this research.

Scandinavian Biogas operates in Sweden as well as in South Korea and is building a new plant to Norway. In Sweden the company has biogas plants in Södertörn, Hendriksdal, and Bromma, in South Korea, they operate a plant in Ulsan. Cofounder and R&D director of Scandinavian Biogas participated in the research on behalf of their company.

The interviewees all represent quite different companies and answer the interview questions from their point of view. Mäkikylä biogas plant is one single plant that is operated by the same company as the waste water treatment plant that is located next to the biogas plant. Mäkikylä biogas plant cooperates with Gasum regarding biogas upgrading and sells the upgraded biogas to Gasum. Gasum operates seven and cooperates with three plants in Finland and is enlarging to Sweden. Scandinavian Biogas has plants both in Sweden and Korea and is enlarging to Norway. The answers regarding Gasum and Scandinavian Biogas is thus not representing one specific plant, but the interviewees answered the questions based on their knowledge of all of the plants operated by their respective companies.

4.2 Performing the content analysis

The interviews were analyzed by content analysis as described in chapter 3.4. The content analysis grid was made based on factors showed in table 1. During the content analysis, the grid was modified by adding four categories to the grid: the process, strengths of the process, weaknesses of the process and finally a category what the interviewee wanted to point out or add at the end of the interview. The grid is showed in attachment 3.

4.3 The production process

The technical solutions of the plants were not discussed in detail in the interviews as the focus of this research is on the profitability rather than technical aspects. The production process type can be thermophilic or mesophilic. The research showed that the type does not so much impact on the production costs, it is more about what feedstock is processed and how it is pretreated and how the digestate is further processed. The process solutions have an effect in the way that if you have a thermophilic process the feedstock breaks down faster and you can receive more raw material to the plant, the down side is that it uses more energy than a mesophilic process. In the end, it is still the overall process that builds up the costs, not single technical choices. The market situation also matters, is the gas sold or is it used to produce electricity and heat and is there then extra heat to be used in the process.

Interesting was that all the interviewees picked different strengths and weaknesses of their processes. One theme that came up in all the interviews was the capacity of the plants. A weakness of Mäkikylä plant is its low capacity and the overall small size of the plant as enlarging it is challenging. In addition, the plant is one lined which brings more challenges. The benefit of economies of large scale was emphasized in the interviews, and it was brought forward that the bigger the plant is, the smaller the payback time is. Several of Gasum’s plants are two lined or are planned to be enlarged to have two lines. Two lines bring flexibility and also a possibility to process different feedstock depending on the line. Gasum usually keeps one of the lines for feedstocks that are seen as clean, for example, waste from the food industry and side streams of other industries, and the other line for wastewater sludge and municipal biowaste. In this way, the digestates are also separate from the two lines, and the digestate from the clean side can more easily be sold as fertilizer.

The strength of Mäkikylä is that the biogas plant is near to the wastewater treatment plant from where wastewater sludge is received to the biogas plant. A challenge at the plant is in addition to the size the deodorization that requires developmental actions in the future. The strength of Gasum is the large network of different plants which gives them different variations and opportunities to compete on the market. A big house also gives a large knowledge base, and possible problems can be solved inside the company, and there is no need to buy it as outside services. The challenge Gasum has is that, even if they have a lot of processing capacity, in some areas they have too little and in some too much capacity, but transporting the feedstock from one plant to another generates costs. The research showed that the use of digestate is challenging at several plants. The digestate that is of wastewater sludge origin is not wanted by the market as there are suspicions of accumulation of different residues in the product. The challenges regarding the use of the digestate will be discussed closer in chapter 4.6 about end products.

The strengths of Scandinavian Biogas lie in their own R&D and that they know the process very well and how to maintain a stable process. The importance of a stable process did not come up in the other interviews, and it was interesting to see that this is something that Scandinavian Biogas is investing in. The challenges Scandinavian Biogas has met on their plant in Södertörn, which now has been in operation for 1,5 years, is the logistics around selling the upgraded biogas.

4.4 Feedstock

The range of feedstocks used is similar at all the plants, but how they are mixed changes depending on the plant. Most commonly used feedstocks are wastewater sludge, biowaste, fats, sugar, and glycerol. In Mäkikylä wastewater sludge and biowaste is mixed. As the process is one lined there is not a possibility to keep the feedstock separate. 65% of the feedstock is wastewater sludge. In Sweden Scandinavian Biogas uses food waste in Södertörn and wastewater sludge in Henriksdal, mixing of the feedstock is not done. Fats and glycerol are used to optimize the process to produce more gas at both sites. In South Korea Scandinavian Biogas mixes sludge and food waste. Mixing different feedstock is seen as a good thing process wise, but the backside is the weak market for the digestate of wastewater sludge origin. At Gasum's plants, wastewater sludge and food waste are run in different lines of the plants that are two lined. Gasum processes 450 000 ton feedstock/year, of the total amount 50% is wastewater sludge. To optimize their gas production, Gasum tries to place the feedstock were they can utilize the gas in the best possible way, but high logistic costs limits transporting the feedstock. In the area of southern Finland, some transporting is done, but longer distances, for example, from or to the Oulu plant is not profitable.

All the plants have gate fees and get payment for the waste that is brought to the plants. In addition to the wastes with gate fees, Scandinavian Biogas buys fats and glycerol to be used in optimizing the process. The amount of the gate fee is dependent on the contract made between the plant and the waste supplier. The research showed that the price is influenced by how easily the feedstock can be handled, how well it produces gas, dry content (so that water is not transported unnecessarily) and also how well it suit into the process. In addition, the market situation impacts the prices. Gasum can to some extent choose what they take in, but in Mäkikylä the competition from nearby biogas plants has affected the availability of feedstock and getting feedstock has been challenging. In Södertörn there is at the time being enough food waste to get even if there is competition and sometimes the waste is transported for quite long distances. The results of the research pointed out that plants have not gone into dumping the prices to get more feedstock even if the competition is hard. The reasons for this are that plants cannot afford it as it would affect the profitability too much and that if the prices are pressed down it is hard to get them up again. The hard competition of feedstock seems to be a challenge for all the biogas plants, and probably the situation is not getting easier in the future if other players then the biogas plants enter the market and start to compete of the same feedstock. The logistics costs are a significant part of the feedstock price, and for that reason, plants try to find feedstocks that come from a close distance. The collection area at Mäkikylä is mostly within a radius of a few 10km from the plant. In Södertörn the collection area is the Stockholm area.

The plant capacities vary in a quite big range. Gasum's plants are from 30 000 ton – 105 000 ton feedstock handling capacity/year, as Mäkikylä is 19 000 ton /year and in Södertörn the plant capacity is 50 000 tons/year. Gasum is enlarging their smallest plant of 30 000 tons to 60 000 tons/year as they see the scale of economy as a big advantage regarding the profitability of biogas plants. Scandinavian Biogas is also seeking for permission to take in more food waste in the future. In Mäkikylä the current equipment would allow for a processing capacity of over 25 000 tons/year, but the environmental permission is restricting the amount to 19 000 tons/year. To enlarge the plant an environmental effects assessment would be required to be done.

Scandinavian Biogas sees the optimization of the process as very important to get the maximum amount of gas produced. In Henriksdal the reactor volume is 35 000m^3 and there about 8 million m^3 methane is produced/year. In Södertörn the same amount of upgraded gas is produced in a 9000 m^3 reactor. In Söderntörn Scandinavian Biogas is responsible for the whole production process and has put a lot of effort into R&D. In Henriksdal Scandinavian Biogas is responsible only for the gas upgrading. To put effort into the R&D and utilize the reactor volumes well can bring considerably more income to the plant.

4.5 Operating and maintenance

All the interviewees express that the far most expensive part of the biogas production process is the operation and maintenance of the pretreatment system. Taxes, insurances and utility costs (chemicals, electricity) on the other hand are not seen as significant costs that would have a big impact on the profitability.

The costs of the pretreatment process are high especially if the pretreatment is made mechanically with crushers, if it is possible to pump the feedstock the costs immediately decrease. The crushers in the pretreatment system wear fast and often need service. In addition, the biowaste often includes plastics that need to be removed. For this reason, the gate fee is lower for clean biowaste and higher for biowaste that includes plastics and other materials that are not suitable for the biogas production process, like sand and glass. It is estimated that the maintenance cost of the pretreatment process is about 3-3,5% of the investment.

In addition to the pretreatment process, the other process part that takes up costs is the digestate handling. Both the centrifugation of it and further transportation, but of course it depends on how you want to treat your digestate. At some plants, Gasum further processes the liquid phase that has come from centrifuging the digestate. They separate the nitrogen from the liquid phase and sell the separated nitrogen as a different product. If the liquid phase is not further processed and the reject water that includes the nitrogen is lead to waste water treatment plant, it also forms high costs.

All interviewees agreed that the digester is a quite passive equipment and does not require much service if the plastic and other unsuitable material has been removed in the pretreatment process. It is estimated that maintenance cost of the digester is about 2% of the investment.

According to the research, the estimated maintenance cost of the CHP unit was 5-10€/MWh. At Mäkikylä a service provider is used, and the CHP unit has a service contract. The payment of the service contract is based on usage hours, and the minimum charge is 2000h/year. For this reason when making process planning the CHP unit should be driven at least 2000h/year at Mäkikylä. Scandinavian Biogas has not got any CHP units as making green electricity in Sweden is not profitable. In South Korea, Scandinavian Biogas has not got a CHP unit yet but is considering investing in one.

For the biogas upgrading an estimated production cost is electricity price + about 0,10€/m^3 methane. Mäkikylä plant and Gasum has a partnership regarding the gas upgrading at Mäkikylä. Gasum has gas upgrading units at their plants that are connected to the gas grid, at off-grid plants the gas is not upgraded.

The capacity of the plant does not have a big impact on the amount of persons working at the plant. This seems to be the case when considering Mäkikylä and

Gasum’s plants, which also indicates that a plant with bigger capacity benefit of scale of economy. At Mäkikylä there are two operators working from 6-14 and one working from 10-18. During evenings and weekends one operator is on call. At Gasum’s plants, there are 3-4 operators/plant. In addition to the operators, the administration is separate, either on-site or working remotely depending on the plant. What is interesting is that at Scandinavian Biogas the number of operators is more than at the Finnish plants. In Bromma and Henriksdal Scandinavian Biogas is responsible for only the gas upgrading. The gas upgrading in Bromma is remote driven, with service twice a week. In Henriksdal, four operators work with the gas upgrading. In Södertörn, four persons work in food waste and five persons in the biogas production. In addition, there is one on site manager in food waste and one in bio gas production.

Deodorization is a challenging part of the process as odor can affect the environment of the plant. The odors are also potential greenhouse gases and cannot for that reason be released into the air. The research shows that a key thing is to have the raw material in closed tanks as most of the odor comes from it. At most of the plants the odor is collected to a central deodorization that includes commonly active carbon filters in addition to some other techniques. Renewing an active carbon filters generates a cost of 6000-7000€/time and other means are seeked for. Scandinavian biogas uses in Söderntörn bio filters and in Ulsan wet scrubber in addition to the active carbon filters. At Gasum wet scrubber and ozone treatment in addition to the active carbon filters is usually used. But at some plants there are challenges with a lot of siloxane in the air and for that reason other means for deodorization is seek for. The high amount of siloxane in the air leads to a need to change the active carbon filters more often which generates costs. At Mäkikylä wet scrubber is used in addition to the active carbon filter. Alternative means, that Gasum is considering to be used, are utilizing the odor in a malodorus gas boiler or burning it by regenerative thermal oxidation (RTO) technique.

4.6 The end products

The use of the raw gas depends on the market situation. In Sweden, it is not profitable to produce green electricity, and for that reason, Scandinavian Biogas upgrades all of the produced gas and sells it for use as vehicle fuel. They have own gas stations at their plants, and they also sell the gas to big biogas consumers, bus and transport companies, or distributors such as AGA and EON. As it is now, it has not been hard for Scandinavian Biogas to find buyers for the gas. The situation regarding usage of biogas is a bit reserved in Sweden at the moment as the Swedish government has not made any decisions about how to treat the biogas after 1.1.2020. Until then the biogas is exempt from CO_2 tax and energy tax. For the users of biogas, this means that it is hard to make decisions about the future and, for example, businesses with big bus fleet are facing a challenge when considering investments in new busses as they don’t know what will happen to the taxes.

Gasum concentrates its business to the gas market. At the on-grid plants, the grid is the logistics channel, and the gas is put into the grid. The grid allows some buffer which is a good side if there is an imbalance in production and usage. On the off-grid plants, the challenge is to find gas users and for that reason, many off-grid plants have CHP units. Gasum seeks for other logistic solutions to be used in the future, such as pressurize transport containers and liquefying the gas. The use of the gas as vehicle fuel is a growing sector, and Gasum has invested in this side both in the grid area and outside it by building gas stations. They see that if there are gas stations available, it will encourage the growing use of gas cars. At the plants where Gasum produces electricity some is used for own uses and the rest is sold. They see that it is best to use the electricity for own use first and then sell what is over, as then there is no need to pay the transfer fee of the electricity, as you would need if you first sell it and then buy it back.

Mäkikylä plant has a contract with Gasum and approximately 2/3 of the produced gas is upgraded and sold to Gasum to the grid. The rest of the gas is used in the CHP unit or burnt in the natural gas boiler. The electricity is sold to KSS Energia, and the heat is used at the biogas plant and Mäkikylä waste water treatment plant.

A big factor that affects the profitability of biogas plants is how the digestate is processed and used. Both in Finland and Sweden, the logistics costs are the biggest expense. The most common application for the digestate is to use it as fertilizer. In Finland, both at Gasum's plants and at Mäkikylä plant the farmers get the digestate for free, and the biogas plants pay for the transport expenses. In Sweden the farmers pay for the digestate, but the income does not cover the real costs, so in the end, the digestate is a cost for the biogas plant. The cost is mostly generated from the logistics. In Sweden, Scandinavian Biogas put a lot of effort in to get the revenue up for the digestate.

In Södertörn, Scandinavian Biogas centrifuges the digestate and they are building an evaporation plant for the reject water so that there is no need to transport extra water with the digestate and also to increase nutrition in the end product. In Södertörn all the digestate is used as fertilizers. In Ulsan, the digestate is burnt. Both at Gasum's plants and at Mäkikylä plant part of the digestate is centrifuged, but a part is further distributed as wet to end users. The use of the digestate is as fertilizers or composting and use as land material. In addition to the most common use of the digestate Gasum is trying to find ways to make new products out from the digestate. One possibility is to take the nitrogen out of the reject water and sell it as one product. They are also researching the possibility to use pyrolysis, and maybe the end product could be something like bio-coal, the future will show. Other technologies that Gasum researches in are the use of struvite precipitation and use of one kind of fast pasteurization.

Mäkikylä has had some challenges to find takers for the digestate and at Gasum the same trend has been seen. It depends on the area how hard it is to find farmers that take the digestate for fertilizer use and also what has been used as feedstock in the biogas process. If waste water sludge is used as feedstock, there is a challenge to get the digestate out, while biowaste feedstock is easier, this is due to suspicions of accumulation of different residues of, for example, antibiotics in the digestate. As discussed earlier in chapter 4.3 the same situation is in Sweden were these feedstocks are not mixed to overcome the problem. The area affects the use of digestate for fertilizer use, if the area near the biogas plant has a lot of cow farms, they have fertilizers of their own (cow manure), and if the area is not dense of growing fields, there is nowhere to spread the product. Both Gasum and Mäkiklä have recently started to cooperate with Soilfood Oy regarding the distribution of the digestate. Soilfood takes care of the sales, marketing, and logistics of the digestate. Both both companies have been satisfied with how the cooperation has started.

Both Gasum and Scandinavian Biogas have some storage space for the digestate at the plants and they transport the digestate directly from the plant storage to the farmers. At Mäkikylä the dry digestate is first transported to Kymenlaakson Jäte Oy from where the digestate is further distributed to the farmers or used in production of mold. For the wet digestate Mäkikylä has a small storage from where the digestate can be transported straight to the farmers. It seems that the extra intermediate storage of the digestate at Kymenlaakson Jäte brings some extra costs to Mäkikylä biogas plant that could be avoided if there would be a possibility to store the digestate at the plant. At Gasum's plants, the wet digestate is usually stored in sack pools that are about 5000m3 in size. From the sack pools, the digestate is distributed to the farmers into similar storage solutions. From there the framers spread the fertilizer into the fields when needed. The dry digestate is stored on asphalt fields from where it is distributed for its use, quite often landfill use.

The challenge of use of end product is to connect the production of the gas with the use. The on-grid plants are in a better position and do not face this problem as clearly as the off-grid plants. The other challenge is the use of the digestate and the high cost of logistics when transporting the digestate to end users. The challenge is especially for the plants that use waste water sludge as feedstock. For these plants, it is important to find new applications for the product.

4.7 Subsidies and political issues

In Finland, there is an option for the biogas plants to either receive investment grant or then they can be in the feed-in-tariff system. One plant cannot get both of the subsidies. Mäkikylä plant has received investment support when it has been built, so it cannot get into the feed-in-tariff system. As Gasum is concentrating on the gas business, they prefer the investment support as in the feed-in-tariff system all the produced gas is bind to produce electricity and heat, as that is where the plant receives the most money from. As the literature shows, this research also supports that the subsidies system can be seen as a bit of a dilemma. When the biogas business is based on receiving subsidies, it is hard to get a plant to be profitable without subsidies. This especially concerns quite small plants; production amount around 2-3 million m3 of methane. To get this business profitable without subsidies plants need to get up in size. When you get up in size, the investment costs/m3 produced methane will decrease.

In Sweden, the political decisions that make biogas profitable as vehicle fuel are that the gas is exempted from CO_2 and energy tax. The tax relief makes that Scandinavian Biogas can keep a price at about 0,70-0,80 SEK/kWh to the end user. In addition, Scandinavian Biogas has applied for some investment grants, but these have not been requirements for building the plants.

A challenge in the biogas business is that the business is under continuous change. The changes are fast, and the plants need to stay on track. Many of the changes come from political decisions, waste law changes, procurement law is renewed and the fertilizer market change, among others. A long-term political will is seen as an important thing for biogas plant profitability. The biogas market is a young market, and the politicians cannot expect anyone to take risks and invest big if a long-term political will that encourages the biofuel market cannot be seen.

The answers show that subsidies and political decision are important for the biogas business. If the laws change often, it is hard for the plants to keep up with the changes. In addition, changes usually require money and in that way influence the profitability of the plants.

4.8 Questionnaire of importance factors

The interviewees answered the questionnaire about how important they see the asked factors to be when considering biogas plants profitability, today and after ten years in 2026. The questionnaire can be seen in attachment 2. It was interesting to see that the answers were quite in line with each other and there was not a very big deviation in the answers. The other interesting finding was that the situation today and after ten years was seen as quite similar. The questionnaire was answered on a Likert scale from 1-5. From the answers the average was calculated and the results are summarized in figure 3. The higher the pillar in the graph is, the more important that factor is seen by the respondents.

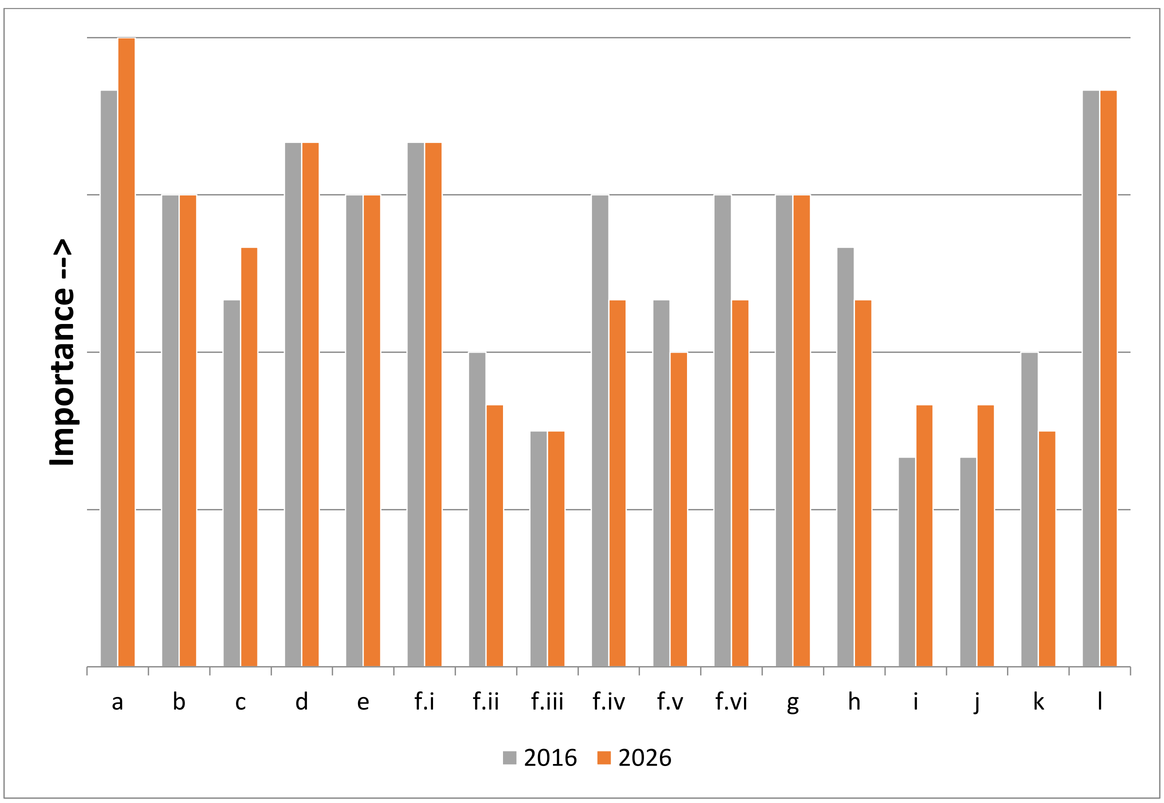


Figure 3. Results of the questionnaire about importance factors. The importance factors asked were: a) Price/income of feedstock, b) Plant capacity, c) Transport distance of feedstock, d) Availability of feedstock, f) Cost of operating and maintenance of: i) feedstock handling system, ii) digester, iii) CHP unit, iv) biogas upgrading, v) labor, vi) utility costs, g) Taxes, h) Subsidies, i) Electricity price, j) Heat price, k) Energy certificates, l) Sale of digestate.

As can be seen in figure 3, the most important factors both now and in the year 2026 are:

- Price/income of feedstock
- Availability of feedstock
- Cost of operating and maintenance of the feedstock handling system
- Sale of digestate

The answers imply that a biogas plant should put most of its efforts on developing and maintain the channels and relationships from where they receive their feedstock. In addition to finding new applications and customers for the digestate can help a biogas plant to reach better profitability.

There were some differences in the answers. In addition to the factors that were seen as important by all of the respondents, the effectiveness of the process, subsidies, utility costs, and taxes were seen as important.

The factors that are seen as less important regarding the profitability of a biogas plant is the cost of operating and maintenance of the digester and CHP unit. Also, electricity price and heat price are seen as nonsignificant factors. The respondents didn’t see the selling of the biogas as challenging, which can be seen as a positive sign regarding the biogas market.

5 CONCLUSION

The key findings will be concluded in this chapter. In addition, the findings are reflected, and managerial implications are given to the commissioner’s plant, Mäkikylä biogas plant, regarding how they could work to increase the profitability of the plant. The thesis process is evaluated and suggestions for further research are given.

5.1 Summary of main findings

This study was based on the research question *How to increase the profitability of Mäkikylä biogas plant?* The main findings were related to plant capacity, choice of feedstock and process optimization, further use of digestate and long-term political will.

The most important thing that arose from the interviews was that the capacity of the plant is a big factor when talking about plant profitability. A big plant can benefit from economies of scale. For example, the number of employees is more or less the same despite the size of the plant. For this reason, Gasum is enlarging their smallest plant with a handling capacity of 30 000 tons feedstock to 60 000 tons feedstock/year.

It is not only important that the overall handling capacity is big, but what feedstock you process. In Sweden biowaste and waste water sludge is not mixed at the plants. This makes the further use of the digestate easier. In Finland Gasum has solved this by having plants with two lines. One line is for waste water sludge and other feedstock that are not seen as clean, the other line is for clean waste, for example, waste from the industry. In Mäkikylä the waste water treatment plant is located just next to the biogas plant and it is easy to transfer the sludge to be processed at the bio gas plant. The down side is the challenge to get digestate out to the fields for use as fertilizer. This will probably not get easier in the future when some industry companies in Finland have started to avoid to buy raw materials that have been grown on fields were digestate of waste water sludge origin have been used as fertilizer. In addition it has been noted in Tekniikka & Talous that some groundwater has been found to be contaminated in Germany due to the use of digestate as fertilizer (Raunio, 2017). It is of great importance for the profitability of biogas plants to find new ways to use the digestate. To increase the profitability at Mäkikylä biogas plant a bigger capacity and a two lined plant is recommended.

As stated before, Mäkikylä biogas plant is located next to the waste water treatment plant and it is easy to get the feedstock from there. Other feedstock used is mostly collected from the Kymenlaakso area mostly within a radius of about a few 10km from the plant. In Södertorn Scandinavian Biogas collects the feedstock from the Stockholm area, which indicates that the collection area of the Södertörn plant is bigger than for Mäkikylä plant. Gasum sometimes transports feedstock for longer distances in the southern area of Finland, but as logistics costs are high, it is obvious that they are trying to minimize the transportation if possible. The competition of feedstock is all the time getting harder and new feedstock sources need to be found for the biogas plants continuously. The competition of biomass will be intensified if coal is forbidden in energy use, as this will further grow the use of biomass, but also at the same time it would grow the market of biogas (Raunio, 2016). To ensure the continuous availability of feedstock the cost-effectiveness of a bigger collection area at Mäkikylä biogas plant should be investigated.

Scandinavian biogas put a lot of effort into R&D and process stability. They buy some fats and glycerol to be used in the production process to optimize the production. In Finland feedstock is not bought. Gasum has a large network of biogas plant and they can in some extent direct the feedstock to the plants where the feedstock and produced gas can be utilized in the best possible way. For Mäkikylä plant, that is a single plant, it is not possible to rearrange the feedstock as Gasum is doing. To increase the profitability by process optimization is a possibility that should be researched more deeply.

The political decisions impact the biogas business tremendously, which makes the business challenging. In Sweden the situation is at the moment reserved as both producers and users of biogas are waiting for political statements what will be the taxation of biogas after 1.1.2020. In Finland, the continuous change of regulations and laws makes the biogas business challenging. The respondents also see that the subsidies are important especially for small biogas plants. For the profitability of biogas production, it is important that a long-term political will can be seen. Biogas plants can promote the cause by delivering their message to politicians when possible.

5.2 Implications for the commissioner

Based on the results from this research, the situation at Mäkikylä biogas plant is remarkably different from Gasum's and Scandinavian biogases. Both Gasum and Scandinavian biogas have several plants and a large plant network. This means that they have big organizations to operate. They have more resources for R&D and also a possibility to specialize biogas plants on different feedstocks. Mäkikylä biogas plant is a single plant with its own operation. The strength of Mäkikylä plant is that the waste water treatment plant is located just next to the biogas plant and the waste water sludge can easily be transferred to the biogas plant.

To increase the profitability of Mäkikylä plant the results of this research indicate the following actions to be taken:

- Research in the possibility to enlarge the plant
- Enlarging the plant so that there are two lines
- Research the cost-effectiveness of enlarging the collection area of the feedstock
- Evaluating possibilities for process optimization
- Distribution of digestate to the farms without intermediate storage outside the plant

The small capacity of Mäkikylä plant has a negative impact on the plant profitability. The research showed that scale of economy benefits the profitability of biogas plants. In addition, with two process lines, it would be possible to produce two kinds of digestate, one with waste water sludge origin and one "cleaner". The available space at Mäkikylä is limited, due to the layout of the plant and constricted interior, which makes enlarging challenging. Even so it is recommended for Mäkikylä biogas plant to research in the possibility to enlarge the plant.

As a new biogas plant near Mäkikylä has been built recently, it has got harder for Mäkikylä to get feedstock and the competition can certainly be seen. The situation will probably not get easier in the future as new players will enter the market and compete for the same biomass. The collection area of the feedstock at Mäkikylä is at the moment Kymenlaakso area. Kymenlaakso is situated not very far from the capital area of Finland. The transportation distance will get longer if feedstock would be transported from the capital area, but would this be a way to ensure the availability of feedstock in the future by bidding on biomass form a bigger collection area? When the competition gets harder in the future, longtime customer relationships can have an impact and give some competitive edge for the feedstock purchases.

In Sweden Scandinavian Biogas buys some fats and glycerol to use in process optimization. Similar optimization is not done in Finland. This research shows that the gas production amount can be significantly higher when the process is optimized. The researcher of this study suggests Mäkikylä biogas plant to research on process optimization and evaluate if this could bring more revenues to the plant and lift the profitability.

The use of the digestate is challenging especially if the digestate is of waste water sludge origin and new ways to utilize the digestate need to be found. The situation is similar for all the plants, and probably the whole business is seeking for new applications. Both Gasum and Scandinavian Biogas is at the moment distributing the digestate straight to the end users from small storages that are located at plants. Mäkikylä biogas plant transports the wet digestate first to an intermediate storage to Kymenlaakso Jäte Oy from where it is further distributed. The transportation of the digestate to the intermediate storage brings extra costs that could be avoided if the distribution could be made straight to the farms. The limiting aspect for Mäkikylä is, also in this case, probably the limited space at the plant. Still, it is recommended for the plant to research in the possibility to avoid the intermediate storage at Kymenlaakson Jäte. The distribution of the wet digestate is made in cooperation with Soilfood Oy. Both Mäkikylä plant and Gasum shortly started the cooperation with Soilfood Oy, and it remains to see how the cooperation works. Both of the companies hope for a fruitful future of the cooperation.

5.3 Suggestions for further research and development based on the evaluation of the own study

The work of this study was aimed to be started in May 2015. The researcher made at that time research of previous thesis made regarding biogas plants and agreed with the commissioner about conducting the study. Due to the personal life situation of the researcher, the actual work of doing the literature review and conducting the interviews was not started before August 2016. The interviews were done in December 2016 and January 2017. The pace of conducting the research was not what the researcher had hoped for. As the biogas business is a fast changing business, it was not the best situation that the finalizing of the work toke time. Still, the researcher is very happy that the research is ready now, and for the babysitting help she has got to be able to arrange time to write this thesis.

The aim of the research was to compare financial statements of several plants to find out how the profitability of the biogas plants was built and where the biggest costs are. Unfortunately, due to the sensitive nature of financials the participating plants were not able to give economic numbers to the researcher. The asked companies were however, willing to give interviews. The interviews were conducted by Skype and face-to-face depending on what was most convenient. The interviews gave interesting information and gave good information for this research. The researcher sees that the results can help several plants to improve their operations and profitability.

After having analyses the results, it can be said that it would have been good to have one more participating company. What was lacking was a company more similar to Mäkikylä biogas plant, a company that operates one plant and preferably uses mainly waste water sludge as feedstock. It would be interesting to get a deeper insight of how single plant companies operate and to compare their operations to Mäkikylä biogas plant.

To gain an even better understanding of the profitability of biogas plants further research that will be done would benefit tremendously if they can receive the financial numbers of the plants operations. The researcher suggests studying more closely the acquisition of feedstock, the pretreatment of the feedstock and the further treatment of the digestate. These seem to be the most onerous and costly parts of the biogas production process.

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LIST OF FIGURES AND TABLES

Appendix 1

INTERVIEW QUESTIONS

1) How does the biogas plant's production process work?

a. What are your strengths?

b. Where do you feel your bottle necks are? Where do you have the possibility to improve most?

2) What is the plant capacity?

a. When considering the feedstock processing capacity?

i. /day, /week, /year?

b. When considering the biogas production capacity?

i. /day, /week, /year?

c. Methane content of the biogas?

i. The received feedstock has an effect on produced biogas amount and methane content, how does this effect the production planning?

d. Number of employees?

e. Burning time of the torch?

3) What feedstocks do you use? From where are they available and how?

a. What are your main feedstocks?

b. How is the availability of the different feedstocks?

c. How do you pretreat the feedstocks? Are there differences depending on the feedstocks?

d. How long are the transport distances of the feedstocks? Do you pay attention to the transport distance when choosing feedstock? How do you take the distance into consideration?

e. Biogas yield of different feedstocks?

f. Do you pay for the feedstock or receive gate fees? How much?

g. Feedstock prices? What factors influences the prices?

4) What are your costs of operating and maintenance?

What costs are related to the following parts of the process?
Which costs has the greatest impact on the plant's profitability?

a. Of the feedstock handling system?

b. Of the digester?

c. Of the CHP unit?

d. Biogas upgrading costs?

e. Utility costs?

f. Costs of deodorization?

g. Do you see that your process is effective? Would there be some aspects to improve?

5) How do you handle/utilize your end products? What is the income/cost of them?

a. Use and income of biogas/upgraded biogas?

b. Use and income of electricity? Own use?

c. Use and income of heat? Own use?

d. Do you sell green energy certificates and receive income from them?

e. How do you handle your digestate?

i. Storing of the digestate and costs related to it?

ii. To whom do you sell the digestate?

iii. For what price do you sell the digestate?

iv. Is there a need to dispose some of the digestate?
How is it handled and what costs does it generate?

f. How do you dispose your waste/reject and what costs are associated to it?

g. How do you dispose the process water and what costs are associated to it?

6) What are your fixed costs?

a. Labour costs?

b. Insurance costs?

c. Tax costs?

7) Do you recieve subsidies from the state/other sources?
a. On what bases?

b. How much?

8) Is there anything you would like to add that you feel is important regarding your income and costs sources?

9) Can you answer the following statements on a scale of 1-5?
(1= Most important, 2=important, 3=neutral, 4=unimportant, 5=not important at all)

Likert scale statements are shown in attachment 2.

Appendix 2

Questionnaire of importance factors

Can you answer the following statements on a scale of 1-5? (1= Most important, 2=important, 3=neutral, 4=unimportant, 5=not important at all)

1) How important do you feel the following factors are today when considering your plant's profitability?

	Most important	Important	Neutral	Unimportant	Not important at all
a. Price/income of feedstock	1	2	3	4	5
b. Plant capacity	1	2	3	4	5
c. Transport distance of feedstock	1	2	3	4	5
d. Availability of feedstock	1	2	3	4	5
e. Effectiveness of the process	1	2	3	4	5
f. Cost of operating and maintenance					
i. feedstock handling system	1	2	3	4	5
ii. Digester	1	2	3	4	5
iii. CHP unit	1	2	3	4	5
iv. biogas upgrading costs	1	2	3	4	5
v. labour costs	1	2	3	4	5
vi. utility costs	1	2	3	4	5
g. Taxes	1	2	3	4	5
h. Subsidies	1	2	3	4	5
i. Electricity price	1	2	3	4	5
j. Heat price	1	2	3	4	5
k. Energy certificates	1	2	3	4	5
l. Sale of digestate	1	2	3	4	5

2) How do you think the situation will change in ten years? What is the importance of the factors year 2026?

	Most important	Important	Neutral	Unimportant	Not important at all
a. Price/income of feedstock	1	2	3	4	5
b. Plant capacity	1	2	3	4	5
c. Transport distance of feedstock	1	2	3	4	5
d. Availability of feedstock	1	2	3	4	5
e. Effectiveness of the process	1	2	3	4	5
f. Cost of operating and maintenance					
i. feedstock handling system	1	2	3	4	5
ii. Digester	1	2	3	4	5
iii. CHP unit	1	2	3	4	5
iv. biogas upgrading costs	1	2	3	4	5
v. labour costs	1	2	3	4	5
vi. utility costs	1	2	3	4	5
g. Taxes	1	2	3	4	5
h. Subsidies	1	2	3	4	5
i. Electricity price	1	2	3	4	5
j. Heat price	1	2	3	4	5
k. Energy certificates	1	2	3	4	5
l. Sale of digestate	1	2	3	4	5

Appendix 3

CONTENT ANALYSIS GRID

Categories/Respondent	Mäkikylän Biolaitos	Gasum	Scandinavian Biogas
The process			
Strenghts of the process			
Weaknesses of the process			
1. Feedstock			
Supply cost			
Gate fees (waste diposal fees)			
Plant capacity			
Tarnsport distances of feedstock			
2. Operating and maintanance			
Feedstock handling system			
Digester			
CHP unit			
Utility costs			
Biogas upgrading cost			
Labour costs			
Taxes			
Incurances			
Deodorization			
3. End products			
Biogas sale			
Electricity sale			
Heat sale			
Green certificates			
Subsidies			
Sale of digestate			
Storing of digestate			
Disposal of digestate			
Disposal of process water			
Other aspects of profitability that is added			