Opinnäytetyö (AMK / YAMK)

Liiketoiminnan kehittäminen

2021

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BENCHMARKING: COST-EFFECTIVENESS COMPARISON OF BIOGAS PLANTS IN FINLAND AND SWEDEN

TURKU AMK

TURKU UNIVERSITY OF APPLIED SCIENCES

OPINNÄYTETYÖ (YAMK) | TIIVISTELMÄ

TURUN AMMATTIKORKEAKOULU

Liiketoiminnan kehittäminen

Kesäkuu 2021 | 57 sivua

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Tässä työssä selvitettiin toimivatko jotkin Gasumin biokaasulaitokset kustannustehokkaammin, kuin toiset ja mikä tämän kustannustehokkuuksien eroavaisuuksien syy on. Lisäksi selvitettiin onko laitoksen kustannustehokkuus suhteessa laitoksen käsittelykapasiteettiin. Työssä tutkittiin myös johtuvatko kustannustehokuuksien erot teknologisista valinnoista laitoksilla ja mitkä teknologiat ovat kustannustehokkaampia.

Opinnäytetyön suorittamiseksi laitosten tulot ja kulut yhteismitallistettiin ja niiden perusteella luotiin vertailtavat mitattavat arvot. Lisäksi havaintojen luotettavuutta arvioitiin asiantuntija haastatteluin.

Työn tuloksen kustannustehokkuuteen löydettiin juuri syitä ja myös teknologisia kustannustehokuutta parantavia havaintoja tehtiin. Kustannustehokuutta voidaan parantaa muun muassa hyödyntämällä biokaasulaitosten koko kapasitetti ja mahdollistamalla kaasun korkea liikevaihto.

ASIASANAT:

benchmarking, biokaasulaitokset, kustannustehokas, vertailu

MASTER’S THESIS | ABSTRACT

TURKU UNIVERSITY OF APPLIED SCIENCES

Business development

June 2021 | 57 pages

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BENCHMARKING: COST-EFFECTIVENESS COMPARISON OF BIOGAS PLANTS IN FINLAND AND SWEDEN

In this work, it was investigated whether some of Gasum's biogas plants operate more cost-effectively than others and what is the exact reason for these differences in cost-effectiveness. In addition, it was investigated whether the cost-effectiveness of the plant is proportional to the processing capacity of the plant. The study also examined whether differences in cost-effectiveness are due to technological choices at facilities and which technologies are more cost-effective.

In order to complete the thesis, the income and expenses of the biogas plants were co-measured and comparable measurable values were created on the basis of them. In addition, the reliability of the findings was assessed through expert interviews.

The reasons for the cost-effectiveness of the result of the work were found, and observations were also made to improve technological cost-effectiveness. Cost efficiency can be improved, among other things, by utilizing the full capacity of biogas plants and enabling high gas turnover.

KEYWORDS:

benchmarking, biogas plants, cost-effectiveness, comparison

CONTENT

LIST OF ABBREVIATIONS

CBG	Comressed BioGas
CHP	Combined Heat & Power
CNG	Compressed Natural Gas
EDIT	Earnings Before Interest and Taxes
EBITDA	Earnings Before Interest, Taxes, Depreciation and Amortization
LBG	Liquefied BioGas
LNG	Liquefied Natural Gas
PDCA	Plan, Do, Check, Act
PnL	Profit and Loss
R&D	Research and Development

1 INTRODUCTION

The goal of the thesis is to compare the biogas plants of Gasum in Finland and Sweden and their processing capacities using Profit and Loss (PnL) data as a basis, and to answer the research question: are plants with a higher capacity more cost-effictive than smaller capacity plants? The thesis in strongly based on PnL information and it also aims to explain if some technical choices or processess are more cost-effecient than others.

The thesis was done by benchmarking the operation, revenues and costs, and it sought to find cost-effectiveness indicators that can be used to find a more efficient way to operate.

For this thesis the following auxiliary questions was prepared:

1. What are the main features that have an impact on cost-effectiveness?
2. Which technical choices in the operation of a biogas plant affect cost-effectivess?

Numerous studies and theses have been conducted on biogas plants and biogas technology, e.g. Mudhoo (2012) studies the pretreatment methods in anaerobic digestion and Välilä (2013) has made a thesis about the use of agricultural waste material in bio production. Many theses focus on increasing the efficiency of biogas production or researching and enhancing quality. Several works have been carried out to study the compositions of the raw materials to be digested and their effect on the compositions of biogas and digestate. Comparative studies of biogas technologies have also been conducted, comparing different technical sub-processes, such as gas purification technologies and digestion treatment technologies.

Benchmarking of biogas plants from an economical point of view is not known to have been reported before. It is also not known if the treatment capacity of biogas plants and its impact on cost-effectiveness have been compared. Also, the aim to compare the technical characteristics of Gasum's existing biogas plants from an economical point of view is conducted with the goal of finding the most technically and economically cost-effective solution for a specific case.

Also for benchmarking, numerous studies and theses have been conducted. Benchmarking can be used, for example, to compare processess in a company. Maikola (2016) mentions that benchmarking is used to compare procurement processess of competitors to the client company with the competitors' help as well as internal benchmarking through brainstorming sessions with the client company's personnel. The external comparisons were unable to be conducted as some of the competitors refused to do benchmarking with the fear or revealing delicate intel. Internal benchmarking was conducted through a series of day-long brainstorming meetings where participants suggested their ideas for best approches and new way of working.

Also, Tormas (2018) used benchmarking on public libraries as a tool to improve and redesign library services. The goal of the thesis was to redesign the Eura main librarys service desk design. In this thesis benchmarking was done by projects, customer inquiries and visits to other public libraries.

In this thesis benchmarking is used to make a financial comparison of biogas plants.

1.1 Purpose and delimitation

This MBA thesis is a case study about a Finnish state owned energy company operating in several countries; it crates a benchmarking comparison on cost-effectiveness of the biogas plants so that the biogas plants can operate with the highest possible technical and financial basis.

In this thesis, first a go through of the theories of business development in general is done, focusing more on the concept of benchmarking. Then a more detailed look into the theory of financial comparison is done and a base is established to to combine these two. Finally a case study is opened for financial comparison of biogas plants profitability in Finland and Sweden followed by cross fuctional benchmarking as far as possible.

The work is mainly done as a literature study, which uses the PnL data from Gasum's production from biogas plants as basic information. The work also interviews production representatives so that differences in the technical capacity of plants can be reliably distinguished and compared.

Finally, findings are presented in cost-effectivess comparison, root causes and development ideas. The chapter Discussion, is reserved for reflection of the work, it's usefulness and reliability as well as possible next steps to improve the business.

The work is limited to Gasum's biogas plants and therefore does not compare the activities of other operators' biogas plants. The work is therefore primarily an internal benchmark to improve cost-efficiency. However, it must be remembered that almost all of Gasum's biogas plants are purchased, and were in operation before acquisiton.

Gasum has only built its first biogas plants in recent years, and even in these biogas plants the technology has been purchased from third parties; Gasum itself has not carried out large-scale technological development, only a small amount of optimization and development work. Gasum therefore does not have its own design activities or actual technology development. Thus, although benchmarking is only done for Gasum's own biogas plants and is considered as internal benchmarking, the plant's capacities and technology choices have been made by the builder of the biogas plant in the past.

Gasum has brought a new way of operating to these acquired plants; i.e. its management culture, financial monitoring, safety culture and the way Gasum operates. The work excludes income and costs that result from the Group's operations and seeks to focus purely on the actual income and costs of the plant.

1.2 Gasum in short

Gasum is a Nordic energy company that specialises in the gas sector. Gasum imports natural gas from Russia by a pipeline and certicates gas from other sources, and promotes a circular economy by handling biodegradable wastes and producing biogas bionutrients from this. Gasum is an employer of over 370 people in Finland, Sweden and Norway. In 2019, Gasum's revenue was 1.128 billion euros with operation profit of 142 million euros (Gasum Financial review 2019, 1-5).

Gasum has diffent gas products such as Compressed Natural Gas (CNG), Compressed Biogas (CBG), Liquefied Natural Gas (LNG) and Liquefied Biogas (LBG). In 2019, Gasum sold 30 TWh natural gas and LNG, and produced 428 MWh of biogas. (Gasum figures and company presentation 2019). In addition, Gasum has LNG terminals and vehicle refilling stations across Finland, Sweden and Norway for heavy duty vehicles, busses and cars (Company in brief and strategy).

Currently Gasum has 17 biogas plants in operation, 9 in Finland and 8 in Sweden. Gasum biogas plants presented in Figure 1, Gasum Biogas Plants.

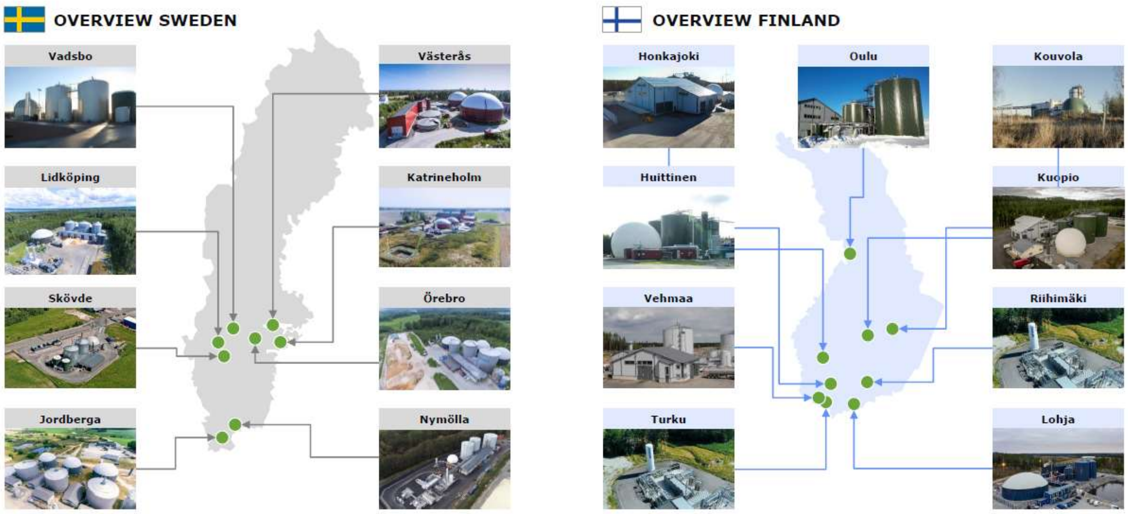

Figure 1. Gasum Biogas Plants (Gasum Bio BU presentation).

2 BUSINESS DEVELOPMENT AND BENCHMARKING

Business development can be done in several ways. The goal is usually to improve the quality or profitability of a product or service. Business development is meant to increase the value for an organization. To do business development different type of tools can be used that guide the work to identify possible problems and overcome them (Pollack 2012).

Development tools can be used also to improve the quality of the business as whole, but more often an indepth look to a situational problem is needed. used. This gives the possibility to find the realtions of the needed improvements. Research and development, or R&D, describes in a business context, the research, development, and innovation functions tasked with improving organisational value (Ojalasalo et al. 2015, 17-18).

Effectiveness can be measured in many different ways. In this thesis, benchmarking was chosen to compare the differences on same business type to better understand how to improve the cost-effectiveness of biogas plants in Finland and Sweden. The benchmarking will be done especially from financial point of view. The theory of financial compasison is studied on chapter 3.

2.1 General development process

From general point of view, a development process can be seen as process where actions follow each other. When examining development as a process, it helps to function in an organized way to take in consideration all the necessary parts, before taking the next steps (Ojalasalo et al. 2015, 22).

Development is fundamentally a change process that should be considered through the PDCA (Plan, Do, Check, Act) cycle. The PDCA cycle is a general tool to continuously improve the quality of change. Multiple iterations of a PDCA cycle are presented in Figure 2, PDCA multicycle, where in the Plan phase, the goal is set and a plan to achieve is made. In the second phase, Do, the necessary actions are taken to adjust to the current situation. In the third phase, Check, the results of the changes are evaluated and finally in Act, which could also be named “Adjust”, the process is improved so that the Plan phase of second cycle can improve even more (Patterson et al. 1996, 53).

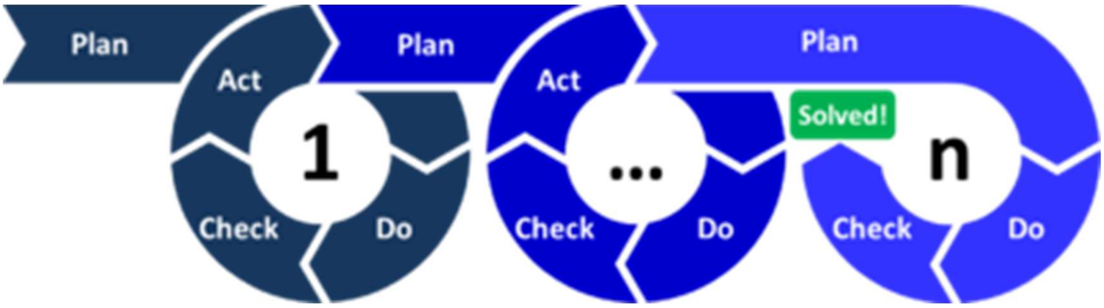

Figure 2. PDCA multicycle (Roser, 2021).

2.2 Measurement of efficiency

The means to measure cost-effectiveness and performance are diverse. Karhu (1999) mentions that when measuring productivity and performance, two main goals can be seen. Firstly, productivity and performance can be used to evaluate how well an action is done. Secondly, performance is the measurement of how well an act is completed when compared to maximum theoretical output. A production is considered efficient when the output cannot be increased by any other way than to sacrifice the effectiveness or performace of another input into that system.

Performance can be measured by several ways such as Data Enveloped Analysis (DEA), Stochastic Data Envelopment Analysis (SDEA), Corrected Ordinary Least Square (COLS) and Stochastic Frontier Analysis (SFA). These can be categorised into parametric and non-parametric, and deterministic and stochastic models, as shown in Table 1 (Syrjänen et al. 2006, 16-32).

Table 1. Performance models.

	Derterministic	**Stochastic**
Parametric	**Corrected ordinary least square (COLS)**	**Stochastic frontier analysis (SFA)**
Non-Parametric	**Data envelopment analysis (DEA)**	**Stochastic data en-velopment analysis (SDEA)**

Syrjänen (2006) explains that while non-parametric models are good at calculating efficiency from data, they are sensitive to data errors which cannot be ruled out, and which are difficult to determine indivual causal factors for. Parametric models are statistic based models that are good at representing a large data set and individual errors do not affect the outcome as much; they do not, however, represent the efficiency of an individual fuction from that group or scale of efficiency. The total factor productivity method (TFP), as described by Mombini et al. (2020), calculates an index figure to each measurable unit and the index figures are compared to the most efficient index. Commonly a Malmqvist index is used.

Benchmarking was chosen because it met the need of comparing the cost-effectiveness between Gasum's plants and would identify the factors causing the differences in cost-effectivenes. Comparison is done partially all the time, by comparing production of biogas, treatment capacity and financial performance, and benchmarking collects the main data of all these and creates the criteria for a hollistic view of the situation. Other means, i.e. DEA, SDEA, COLS, SFA and TFP would have needed a comparison group data for the calculations, which were not available, and thus benchmarking was the most practical option remaining.

2.3 Benchmarking in short

Benchmarking is a tool used to develop a certain or specific part of business or process. Benchmarking is copying what works from other sources – learning and sharing by comparing. Benchmarking starts with first evaluating your own operations, its strengths and weaknessess and then trying to understand what and how others are doing it better (Patterson et al. 1996, 4).

Patterson (1996) writes that benchmarking should not always be limited to similar industries, but a variety of industries can be used in many cases. Used partners of benchmarking should should be top of their field. For example billing and collections can be compared to service providers on top of their field, as well as warehouse operations, process quality or world-class production scheduling. When benchmarking is done right, it will cause a change in the organisation. They key is to identify the areas with the greatest leverage to make significant improvements. It shoud start with customer requirements, by indentifying what are the customer expectations and demand. When doing benchmarking a cross section of workers and managers should participate in the benchmarking. The goal of benchmarking should be set, that is realistic and achievable, but ambitious. Benchmarking can be a way to world-class operations.

2.4 Types of benchmarking

Patterson identified six types of benchmarking in his book (Patterson et al. 1996, 31). Benchmarking started with the industrial sector, but it's use has expanded into services, financial and government sectors and there have been signs of benchmarking being used in education, too. The following types of benchmarking are differect methods for different kind and size of companies.

Internal benchmarking

The first goal must be to know yourself. This is done by internal benchmarking, which can be done in six months. Internal benchmarking is the easiest way to start and it can be very fruitful. Benchmarking can be done within units to find the best practices. Internal benchmarking is usually easy and cheap, as both sides have the same goal to improve and no fear of leaking intel to outside of company need to be feared (Patterson et al. 1996, 31).

Competitive benchmarking

Competitve benchmarking is one of the most difficult kinds. This might leave a company vulnerable to leaking secrets and it should only be done with companies in the same field, product of process. When competitor benchmarking is done, it should benefit both companies. Competitive benchmarking is especially good, as the comperable data is directly usable (Patterson et al. 1996, 32-33).

Collaborative benchmarking

Collaborative benchmarking is a form of benchmarking where companies can share and gain knowledge anonymously. This can be done, for example, through surveys.

Collaborative benchmarking is usually also cheap and results come in fast (Patterson et al. 1996, 34).

Shadow benchmarking

Shadow benchmarking is benchmarking your oponent without them knowing. This type of benchmarking does not share information and aim for mutual benefition. Shadow benchmarking is usually done to processess that are common across both partners (Patterson et al. 1996, 35).

Functional benchmarking

Functional benchmarking compares methods to close to identical businessess. This type of benchmarking is usually done to industry leaders when the company's goal is further into the future. Fuctional benchmarking might take some time and results are not certain and always trust worthy (Patterson et al. 1996, 35).

World-class benchmarking

World-class benchmarking looks at global best-practice regadless of industry. World-class benchmarking can be difficult to manage, as participants are usually reluctant for co-operation. Setting up the right questionnaire that convinces the participant to answer might also be difficult. The up side is that world-class benchmarking has the highest potential to provide valuable insights, if the ideas can be passed through leadership – and here lies the next problem: gathered information might require fundamental changes in leadership (Patterson et al. 1996, 36).

2.5 A succesful benchmark

Patterson (1996) defines some key needs that a organisation needs for a succesful benchmark

- Absolute and total leadership commitment
- Being open to change and other, different ideas

- Truly knowing your own organisation’s operations
- Being willing to share the results of your benchmarking study with you benchmarking partner
- A leadership dedicated to continuos quality improvement through benchmarking

These qualities are needed so that the planned benchmarking can be done right and the results are reliable. Benchmarking should consider what is important to the business, makes up the highest costs and what could benefit most for the improvement on quality or, for example, cycle time.

Benchmarking can also be divided in to steps that help you control your benchmarking. The first step is to determine what you bechmark. The benchmarking should have a critical impact to you company. Next up is identifying the benchmarking companies which you want to benchmark against. The companies should be better than you are in the selected field. Then it is to time record current performance by measuring and analyzing the methods used and writing down the areas improvement is needed on. When you understand this, it is time to learn how they do it. Try to understand their processess. Again measure and analyse how and why they are better, compare the results and do tests. When all the data is collected you can understand the gaps and create goals. Establish bridges, ways to improve, simple steps to take so that you can reach their level and go beyond. Adapt and implement the best methods and practices. And finally, repeat the cycle. Undertand that, doing this once is not enough, but it is a continous cycle of improvement (Tuominen, 2016, 6-9).

3 THEORY – FINANCIAL COMPARISON

A financial comparison can be made between companies or, for example, business units of the same company as this thesis will do. Financial comparison often compares ratios of each company's financial statements. The comparison can be made to net profit, expenses, equity ratio, return on equity, return on investment or earnings before interest, taxes, depreciation and amortitization, to mention a few.

In this thesis, I will concentrate on Gasum's incomes and expenses in its biogas business unit, specifically comparing different biogas plants and operational performance in Finland and Sweden.

3.1 Operational profit and loss

Operational profit and loss consists of all the incomes and expenses that a business has. It is a financial statement that sums up revenue, income, and expenses incurred over a period of time, usually quarterly, semi-annually, or annually. A PnL is one of the key reports that provides information on a company's financial situation (Fernando, 2021).

Fernando (2021) continues to explain, that a PnL specifies the general way of presenting a company's finances beginning with a general presentation of the company's turnover, sales revenue and operating expenses, including, for example, material and production costs, changes in inventories and the cost of internal and external services. Personnel and social costs are also included as deductible costs. A company can also have a wide variety of other costs depending on the industry, such as vehicle costs, rents, insurance, maintenance costs, marketing and administrative costs.

After these deductions the operating profit, EBITDA, is shown. EBITDA describes the amount of money a company retains when variable and fixed costs are deducted from the revenue. As this continues, the deduction of amortization and depreciation, there will be EBIT, which describes operating income before interest and taxes. And as futher deduction of interest and taxes the company's net income in shown (Fernando, 2021).

Apart from these key figures, there are other specific profitability indicators targeted at lenders and investors. The key figures are generally derived from other key figures and also function as ratio key figures.

Additional figues such as the Net Profit margin; various liquidity ratios, such as the Current Ratio, Quick Ratio, Cash Ratio and Inventory Turnover; profitability ratios, such as the Return On Assets, Return On Equity and Return On Interest; and the final group of general rations, the valuation rations, including, Price-to-Earnings, Price-to-Book, Price-to-Sales and Price-to-Cash Flow are also commonly used.

3.2 Special financial key figures

All the key figures mentioned in 3.1. are general key figures. In addition to these financial indicators, it is also useful to compare the operational indicators of the activity, as this thesis will mainly focus on. In fact, the indicators mentioned above would not provide the information needed.

The idea of the thesis is to create Gasum's own Key Performance Indicators (KPIs), that describe the technical, biological or other perfomance measure of a biogas plant. These could be the ratio of capacity to revenues and costs, and the relationship of both to the selected technologies in raw material processing, biogas production and digestate treatment. Each measure will be presented from an economical perspective so comparisons can provide an indicator of economical viability and cost-effectiveness. The aim is also to further guide Gasum in making more cost-effective decisions for a possible new biogas plant, and in developing the capacity and technology choices of current plants to be more cost-effective.

3.3 Comparing key figures

Comparing numbers between different companies is more straightforward and reliable when companies are in the same industry and operate in the same way, correspondingly, comparisons become increasingly unreliable as companies diverge. For in-house analysis, PnL comparisons are usually straightforward when different manufacturing plants in the same firm operate on the same principles.

The main income of a biogas plant in different countries comes from different sources, as well as expenses. These relationships between different revenues and expenditures is discussed in more detail in Chapter 5.

4 FINANCIAL STUDY OF BIOGAS PLANTS

This financial comparison will be made between Finnish and Swedish biogas plants' operational figures from 2020 PnLs. Analysed data was retrieved from Gasum's 2020 PnL reports and internal biogas plant online reporting through Microsoft Power BI.

4.1 Exclusion on comparison

To make a reliable comparison, some groud rules must be set and exclusions made. I will exclude most subsidy based income and investment aids that might affect the results. Limitations need to be made on the data being processed because certain PnL accounts would give misleading results. Certain accounts were removed from the comparison partly because there were no records for them. These accounts are used at the Group level and are therefore not recorded on the biogas plants' PnL sheets'.

Some of the PnL sheets' lines were deleted because the entries were very small and irrelevant as a whole and some because they do not affect the utilization rate, capacity or technology of the biogas plant. These include, for example, IT costs, cleaning costs, bank charges, i.e. Some of the accounts have been shown for comparison purposes in order to assess the impact on the overall economy, but not to delve into them.

Finally, only the EBITDA level is compared, i.e. the share of investments, financing and their depreciation and taxes are not taken into account. Differentiating between investment and depreciation is challenging as the size of the investment and the amount of depreciation affect profitability if a new biogas plant is built. But this information is largely no longer available or has changed significantly; including these items would distort the analysis and lead to ill-informed decision making. The purpose of this thesis is not to provide basic information for the investment plan, but to compare the cost-effectiveness of existing biogas plants at this time and to try to find ways to improve the current operating model by learning from existing plants.

4.2 General incomes and expenditures

The turnover of biogas plants consists mainly, depending on the country, of either the sale of waste treatment services or the sale of recycled nutrient as a final product, as well as the sale of biogas in its various forms. Country-specific differences are discussed in more detail in Section 4.3. Differences in Finland and Sweden.

Otherwise, spending in both countries is made up of very similar types of purchases such as transportation costs, maintenance and repair, service purchases and materials, and staff costs - to name a few.

4.2.1 General PnL Finland and technological differences

In Finland, the revenues of biogas plants mainly consist of sales of waste treatment services – also called gate fee - and sales of biogas in various forms, such as raw gas and its various processed forms, Compressed Biogas (CBG) and Liquefied Biogas (LBG), and rarely also directly as heat and electricity.

In Finland, fertilizer sales rarely generate a positive income stream. Only two plants in Finland produce processed products from digestate to such an extent that they generate an income. In order to produce a highly processed digestate end product, a large investment is required and the payback period of which is not profitable in a low-capacity biogas plant (Gasum, reject water options).

Finnish biogas plants are mainly built on the same assembilies, as each other. Plants always have a waste reception first, which can be implemented with different technologies depending on the fraction being treated. The bulky waste fractions are received in a basin or funnel from where it is further pumped into the process. The biowaste is received in a bunker, from where it is further fed to equipment that separates the organic and inorganic fractions.

After receipt of the sludge and possible interim storage, depending on the plant solution, there is either pre-hygienisation and digestion, or digestion and post-hygienisation. The order of sanitation in relation to the digester has a reasonable effect on the capacity of the plant and the amount of digestate formed. After the digester, two different monitored streams are formed, which are biogas and digestate.

Biogas can be utilized as such or further processed. There are two different technologies for biogas processing in Gasum: water scrubber and membrane technology; these remove gas pollutants and carbon dioxide, producing almost pure methane. Methane is usually pressurized, in which case it is called Compressed Biogas (CBG). Almost pure methane can still be liquefied to produce Liquefied Biogas (LBG), as is now being done at one Finnish biogas plant. The profitability of LBG's production is also affected by the plant's gas production capacity.

The digestate can be used in agriculture processes. Generally, the digestate is separated mechanically, again yielding two fractions - dry matter and reject water. The dry matter is a fertilizer suitable for agriculture. Reject water is also suitable in certain cases as a nutrient, or it can be further processed into nitrogen-phosphorus concentrate or ammonium water. Also condensate is formed in all reject water processing solutions in Gasum.

The production cost of processed nutrient fractions is significantly higher than the income from the sale of the nutrient fraction. The profitability of the investment is not based on a significant increase in net sales but on a decrease in expenses. If the processed products were not produced, there would be significantly more “disposable” digestate, which would incur greater costs than the costs occured in the amortization period of the investment (Gasum, reject water options).

4.2.2 General PnL Sweden and technological differences

In Swedish biogas plants, revenues consist mainly of the sale of biogas in various forms, mainly refined and liquefied, and the sale of fertilizer products. Swedish biogas plants do not receive the so-called gate fee, but buy the raw material for digestion. In addition, biogas plants sell nutrient-rich digestate as recycled fertilizer to agriculture.

Swedish biogas plants are technically simpler, but consist in part of the same sub-processes. Similarly, Swedish biogas plants have a sludge reception to which bulk products are received, but none of the biogas plants has a biowaste reception equipment and therefore no such investment has been required.

After raw material receipton, biogas plants in certain cases have a pre-digestion, which acts as an intermediate storage before the digestion plant, just like Finnish plants. After the pre-digester is a digester or sanitation, in either order.

Biogas is almost always processed in Swedish plants, only gas for own use is left unprocessed and only roughly cleaned of contaminants. Correspondingly, two different refining technologies are in use in Gasum's Swedish biogas plants, and one plant will start producing liquefied biogas during 2021. There are therefore no significant differences between the Finnish and Swedish plants in terms of gas processing.

Digestion residue in Sweden is always used as such and is not further processed in any way, only seldomly separated. This is a significant difference compared to Finland.

4.3 Differences in Finland and Sweden

There are fundamental differences in the operations and production of biogas plants in Finland and Sweden, which affect the country-by-country comparison and must be taken into account.

In Finland, biogas plants sell a waste treatment service, from which the plants receive a so-called gate fee. Digestion residues from biogas plants are rarely a source of income, although digestate and its processed forms contain important nutrients for agriculture and chemicals for industry. In certain Finnish plants, nutrient fractions have been processed to such an extent that the industry is willing to pay for them, but these highly processed products require large investments and high operating costs. The raw material processed in Sweden is purchased for the plant and therefore does not generate revenue, but is shown as an expense. Gas generates turnover in a similar way, as in Finland, but is of much more value. Otherwise, income is derived from nutrient sales, i.e., quite the opposite of that in Finland. Swedish plants sell nutrient-rich digestate to agriculture as a recycled nutrient.

Finnish biogas plants are somewhat more complicated in terms of technology comparison than Swedish biogas plants. Due to this, Finnish biogas plants also generally have more equipment, which causes a greater need for investment and a longer payback period, amortization and high maintenance costs.

One significant difference is the waste fractions to be treated and its need for processing, more precisely. In Finland, one of the streams to be treated is biowaste, which consists of biowaste from industry, shops, households and restaurants. These fractions usually require pretreatment in which an inorganic portion such as plastic, metal and sand is separated from the waste fraction. Swedish biogas plants do not process waste fractions that require pre-treatment, but all fractions are fed almost as such to the reception and digestion plant, only water is used for dilution. Plants have at most shredder pumps or stone traps to do a rough pretreatment.

Another significant difference is the further processing of the digestate. The Swedish plants do not carry out further processing of the digestate, as the digestate residue is already suitable for agriculture and in a marketable form.

There is no market for digestate in Finland as such. The digestate is taken to agriculture, but the recipient is generally paid for the reception and mixed in a sludge tank, for example with pig slurry. The digestate can be further processed, in which case the first step is always separation. Separation gives two fractions, reject water and dry matter. There is also no market for the separated dry matter from which revenue would be generated but the recipient is again paid a reception fee. However, the separation achieves a significantly lower mass when the reject water can be partially reused in the biogas plant as a dilutent. In certain cases, the excess reject water is suitable as a nutrient for the industry, whereby it can be disposed of at no cost or at a much lower cost. The next step in further processing is the treatment of reject water into a more advanced product. In two Finnish biogas plants, reject water can be processed into nutrient products of economic value. However, the value of further processed products, such as nitrogen-phosphorus concentrate and ammonium water, does not alone recoup the investment, but processing significantly reduces costs in the long run for the overall economy and makes the investment profitable.

4.3.1 Subsidies and investment aids

Over the past ten years, it has been possible for biogas plants to apply for various subsidies in Finland and Sweden. Some of these subsidies are no longer available, but new ones have been implemented. In Finland, for example, there was a feed-in tariff granted by the Energy Market Authority and investment support from the Ministry of Employment and the Economy (Motiva). In Sweden, biogas production is also supported, for example through the Klimatklivet project (NS Energy). These subsidies support biogas plants through, among other things, energy production or investment.

Various subsidies enable the construction of biogas plants or the production of biogas. Grants may distort the study of cost-effectiveness and for this thesis if they appear directly on the PnL sheet if the grant is not differentiated in accounting.

Swedish biogas plants generally receive production subsidies for biogas, which can be in the order of 30-40% of total gas turnover. In Finland, none of Gasum's biogas plants currently receive gas production support, but some of the plants have received investment support.

5 BENCHMARKING OF BIOGAS PLANTS

In this thesis, a benchmarking comparison was chosen to determine the efficiency by normalizing the biogas plants according to the key preformance indicators, and then comparing the efficiency between the plants. By measuring efficiency with such meters, resource efficiency can be determined in isolation from flow efficiencies such as those in Lean principles. However, resource efficiency in a production economy is usually a good way to measure efficiency when the goal is to produce as much of the final product as possible, which in this case is the amount of energy produced or tons of raw material processed.

5.1 Establishing the base line

In order to make the data to be processed as comparable as possible, certain modifications must be made to the data. This means that some plants were removed from the comparison because there was no entry for the 2020 PnL. Some plants were also removed because the plants have been with Gasum for less than a year and PnL data were incomplete. In addition, the data from one biogas plant and the processing plant were combined, as they were in PnL at their own cost centers.

The plants have been designated as A and B plants, with A plants being Swedish production plants and B plants being Finnish. Five plants were compared for Sweden and eight for Finland.

When comparing plants, the purpose is to present the production efficiency of the plants, for example by comparing the energy production of the plants in relation to the processing capacity. However, with regard to processing capacity, it should be noted that capacity can be presented in a few different ways.

5.2 Capacity differences

One capacity is the treatment capacity of the plant in accordance with the environmental permit. This is the so-called legal capacity, which is not necessarily the same as the plant's otherwise calculated capacities, and is the capacity according to the environmental permit issued by the authority to handle raw materials.

Another form of capacity representation is biological capacity. As the operation of a biogas plant is based on the activity of living microbes to produce methane, the conditions must be created for them to operate as optimally as possible. Thus, biological capacity describes the capacity of methanogenic bacteria to form methane under given conditions. Kymäläinen and Pakarinen (2015) describe that biological capacity is affected by the properties of the raw material to be treated, such as the dry matter content of the raw material, the proportion of organically degradable solids and, for example, inhibitory compounds such as free nitrogen in various forms.

The third capacity is the technical capacity of the plant. This capacity describes the capacity of the plant’s process equipment to handle the material, such as sizing parameters for pumps and pipes, and tank volume.

There may be different limiting capacities for each plant, which will be considered in more detail for the plants when making a cost-effectiveness comparison.

5.3 Benchmarking profit in Finland

The income of Finnish biogas plants mainly consists of the sale of waste treatment services and biogas in various forms. To a lesser extent, there is also revenue from the sale of nutrients and the sale of electricity and heat. Revenues are shown in Figure 3.

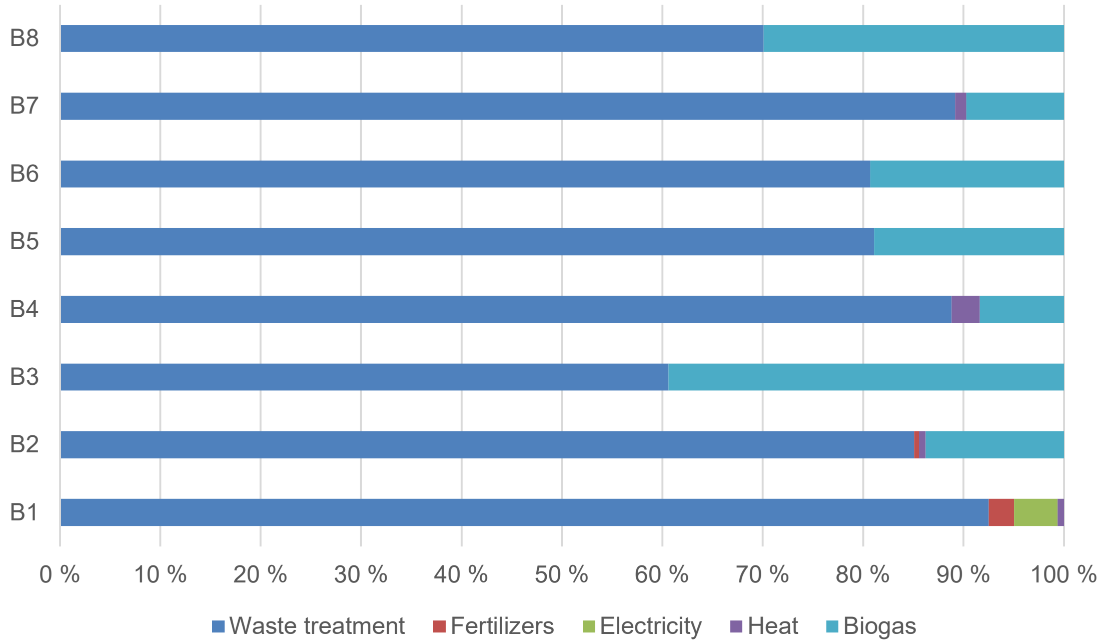

Figure 3. Revenue categories in Finland.

Figure 3 shows most of the total turnover comes from the sale of the waste treatment service at each plant B1-B8; this revenue accounts for about 83% of total net sales. It is thus clearly noticeable that the profitability of Finnish biogas plants is strongly based on the so-called gate fees, i.e. the sale of a waste treatment service. Gas sales have a small share, and it should be noted that the share of gas sales varies significantly from plant to plant, depending on the technology used, the gas sales contract and the price obtained. The reasons behind different revenues of biogas are explained in more detail in the chapters to follow.

B1

At plant B1, the waste treatment service generates about 92% of the turnover. In this plant, gas is utilized by the CHP unit for electricity and heat, which accounts for about 5% of turnover, the rest being nutrient sales.

The annual energy yield of plant B1 was about 28 GWh in 2020 and the plant's utilization rate was then about 76% (Gasum, production report Q1-2021) of the technical capacity with the current raw materials. Even if the plant's operating capacity were increased to 100%, there would be no significant increase in turnover from biogas utilization.

However, Plant B1 is the best performing biogas plants in terms of EBITDA % in the first quarter of 2021. This is mainly due to the good gate fee price of the raw material being processed.

In chapter 5.5, it is presented how turnover could increase at Plant B1 if the current CHP were to be replaced by a biogas upgrading plant based on water scubber technology.

B2

Plant B2 is more complex in terms of turnover, although most of the turnover still comes from the waste treatment service, generating about 81% of the turnover. At plant B2, the gas is refined by membrane technology and liquefied to LBG, where the gas already has value, accounting for about 14% of the plant's turnover. Other revenues from the plant include sales of nutrients and sales of electricity and heat.

Plant B2 is also a very productive plant, although only 77 % of the plant's capacity according to the environmental permit is in use (Gasum, production report Q1-2021). The technical capacity of the plant is still a bit unclear as it has gone through a significant modernization project and extension project. Its planned capacity is 115,000 t / a, but it is assumed that the capacity will actually be somewhat higher than this. In 2020, the plant produced about 42 GWh of biogas.

Plants B1 and B2 also have in common the digestate processing technology, which is unique compared to other plants.

B3

Plant B3 is a very typical biogas plant in Gasum's Finnish plant network, with a planned technical capacity of 60,000 t / a. The technology is relatively simple compared to Finnish plants, but the specialty for plant B3 is its organic status.

Plant B3 mainly treats only packaged and unpackaged biowaste as well as a small amount of other waste fractions, which are not, however, waste of human origin from the wastewater treatment plant. The aim is to produce a final product that would have a higher value in agriculture due to its organic status and therefore lower the cost of the final product. These costs are discussed in more detail in Section 5.4.

In 2020, approximately 60 % of Plant B3's net sales came from sales of waste treatment services and a significant 39% from sales of gas. At plant B3, the gas is subjected to only a rough treatment, in which impurities such as nitrogen and sulfur compounds and organic volatile acids are removed. After this purification, the gas is sold as raw gas to the buyer. Raw gas has a relatively good price compared to purification technology, although more turnover would be available if it were refined to CBG level. Annual gas production is about 23 GWh.

However, the Plant B3 EBITDA % of the plant is one of the weakest in the network. The operating capacity compared to the technical capacity has been only 60% (Gasum, production report Q1-2021), which is not a limiting factor for the plant. As the plant mainly treats only biowaste - and due to the equipment for the treatment of the biowaste selected there - the biological treatment capacity becomes the limiting treatment capacity. Plant B3 is thus limited by the organic load due to the high nutritional value of the bio-waste and the low dry matter content of the bio-waste, rather than the technical capacity. If the plant's operating capacity were to be increased and turnover increased, it would have to find a raw material with a relatively low nutritional value compared to biowaste, a higher dry matter content and, this all with a relatively good gate fee. Finding such a waste fraction is challenging. The plant's energy yield in 2020 was about 22 GWh.

B4

Plant B4 is also simple in terms of digestion plant technology, and the plant does not treat biowaste. The planned technical capacity of the plant is 60,000 t / a. 85 % of the plant's turnover comes from waste treatment sales. At plant B4, biogas is sold both raw and processed. For the treatment of raw gas, it is subjected only to a coarse treatment similar to that of plant B3 when sold as such. In the case of refined gas, the raw gas is processed by membrane technology into pure biomethane, after which the gas is compressed into transport containers and transported to the place of use. Sales of raw gas account for 3 % of net sales and sales of refined gas for 7 % of net sales. In addition, the plant has heat sales, which account for about 2 % of net sales in 2020.

The biogas plant’s EBITDA % is also quite weak compared to the network. However, it must be remembered that plant B4 also does not make full use of its technical capacity, as its location makes it difficult for the plant to find a good raw material with a significant turnover. The plant used only about 46 % of its technical capacity during Q1 in 2021.

The plant produced about 20 GWh of biogas per year (Gasum, production report Q1-2021).

B5

Plant B5 receives a wide range of all organically degradable waste as raw materials and its operating capacity is more than 100% of the planned technical capacity of 60,000 t / a. Over the years, small technical changes have been made to the plant, which together with its excellent location, enable even higher operating capacity than the design value,. About 77 % of the plant's net sales come from waste treatment sales and about 18 % from gas sales. Plant B5 also does not process gas, only conducting a rough cleaning to resell as raw gas.

The plant's profitability seems to be supported by its high utilization rate, i.e. its good location and thus its good raw material handling price, as well as its versatile reception repertoire and low-cost gas pre-treatment compared to the sales price. The plant produces about 32 GWh of biogas annually.

B6

Plant B6 also treats all organically degradable waste fractions in a versatile way with the same technical solution as plants B3 and B5. 79 % of the plant's turnover comes from the sale of waste treatment services. However, unlike the above-mentioned plants, in plant B6 the gas is mainly purified by membrane technology and transported by containers to the place of use. Gas sales account for 19 % of net sales.

The plant produces 31 GWh of biogas annually and the utilization rate is also quite good, 87 % (Gasum, production report Q1-2021) of the technical capacity.

B7

Plant B8 is the smallest plant in the network. Its planned treatment capacity is only 20,000 t / a and the technical solutions also differ from the rest of the plant network, but it is able to handle all organically degradable waste fractions in a versatile way. 89 % of the plant's net sales come from sales of waste treatment services and about 10 % from sales of biogas. At plant B8, the gas is purified by water scrubbing technology and fed into the natural gas network.

During 2020, the plant's utilization rate has been high at 89 % (Gasum, production report Q1-2021). This is due to the high maintenance costs, leading to maintenance debt. During the first quarter of 2021, EBITDA % is barely positive, with a roughly equivalent utilization rate. The plant's energy yield is in the order of 12 GWh per year.

B8

Plant B8 is a slightly larger plant with a technical capacity of about 75,000 t / a, which receives all organically degradable waste fractions. 74 % of the plant's net sales come from the sale of waste treatment services and about 20 % from the sale of gas. At plant B8, the gas is purified by water scrubbing technology and fed into the natural gas network. 70 % of the plant's technical capacity has been in use during Q1 2021 (Gasum, production report Q1-2021) and annual gas production approximately 42 GWh.

5.4 Profits all together

Figure 4 summarizes the ratios of the plants' waste treatment service sales and biogas sales to EBITDA %.

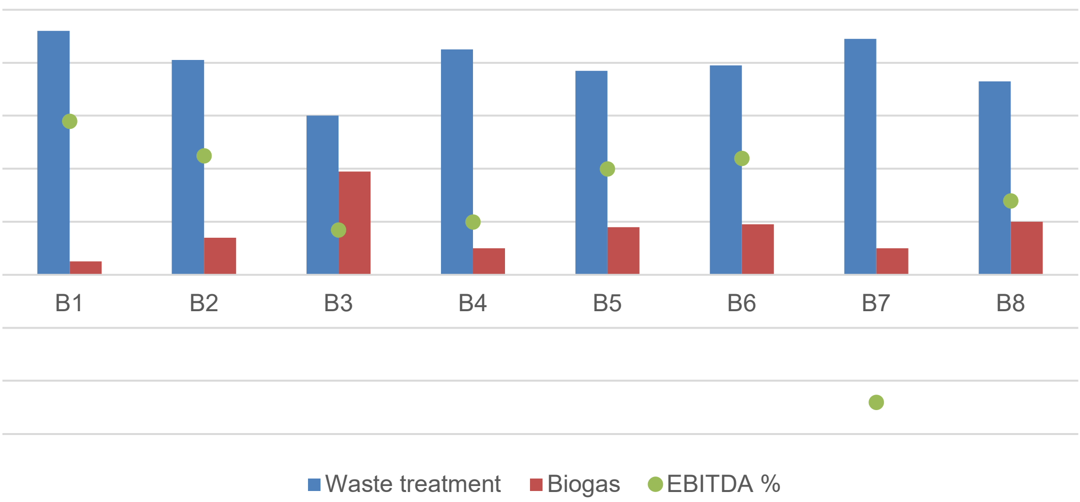

Figure 4. Waste treatment and Biogas sales compared to EBITDA %.

Sales of waste treatment services account for a significantly higher share of turnover in all plants except B3. At plants B5, B6 and B8, biogas already accounts for almost 20 % of net sales.

The share of EBITDA is highest at plant B1, where the value of gas is the lowest. For this reason, it will be interesting to find out how the profitability would change if the biogas produced had relatively similar revenue as other plants where the biogas is processed into biomethane. This is briefly examined in chapter 5.5.

Plant B3's higher revenue from gas is based on a good selling price for raw gas. In practice, at plant B3, the biogas is only roughly cleaned of impurities, but no carbon dioxide is removed. Coarse cleaning is cost-effective in relation to the selling price, as the plant sells the gas to a company that receives production subsidies for further processing the gas into electricity and heat at a CHP unit. That is unlike plant B1, where CHP unit's electricity does not receive production subsidies. It would therefore appear that even a low-utilization plant can operate productively if a sufficiently high value is obtained for biogas.

Figure 5 shows the total biogas yield and EBITDA % as well as the plant's relevant capacity.

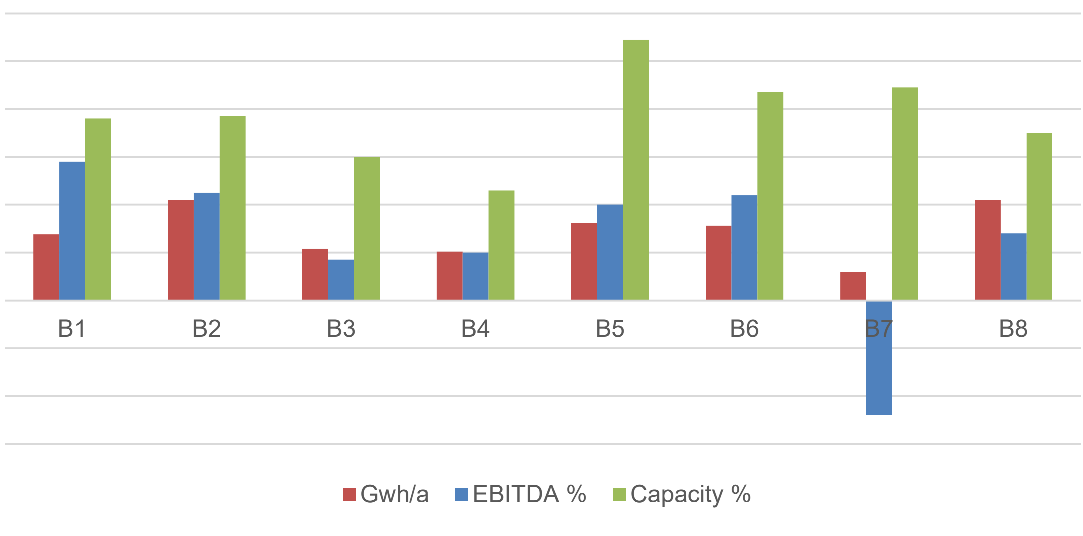

Figure 5. Biogas production (GWh), Capacity utilization % and EBITDA %.

Plants B2 and B8 produce the most gas at roughly the same utilization rate (B2 77 %, B8 70 %). But the EBITDA % for plant B2 is 17 percentage points higher than that of plant B8. With plant B2 having a total capacity of 115,000 t / a and plant B8 having a total capacity of 75,000 t / a, the actual annual treatment volumes are 88,550 t / a and 52,500 t / a, respectively. Thus, the profitability of plant B2 is better, although the operating capacity of the plants is roughly the same, but plant B2 handles about 36,000 tons more waste than plant B8. If we still take into account the revenue from the sale of biogas - which is 3 percentage points lower at plant B8 than at plant B2 - it seems that plant B2 operates more cost-effectively than plant B8.

The cost-effectiveness of a biogas plant is a complex and difficult-to-determine entity, but by exaggerating and simplifying revenues and expenditures, it would appear that a plant with a higher treatment capacity is more cost-effective than a plant with a lower treatment capacity. However, the conclusion based on PnL data alone is insufficient and would require much more in-depth investigation for the claim to be considered true. In addition, the conclusion is influenced by unreliable PnL data and entries in it. It must also be borne in mind that the cost-effectiveness between the two plants is also strongly based on the location of the plant and thus on the potential raw materials.

In addition, the low EBITDA % of facility B7 required further clarification. If we compare the turnover of the B7 waste treatment plant with the next smallest plants, B3 and B4, it is found that the turnover is 77 % and 55 % of those plants, respectively. Plant B7 thus has a high utilization rate, but although at almost maximum capacity, it does not produce as much as plants B3 and B4. It would therefore appear that a high utilization rate alone is not sufficient to ensure a good return. Taking into account the turnover from biogas sales, it can be observed that the turnover from gas sales at plant B7 is 14 % and 52 % from plants B3 and B4, respectively. Thus, a small total capacity plant will naturally also produce less gas and therefore no significant revenue will be generated from biogas. It would therefore appear that the profitability of a biogas plant correlates to some extent with the total capacity of the plant with Finnish biogas plants.

The capacity ratios are shown in Figure 6.

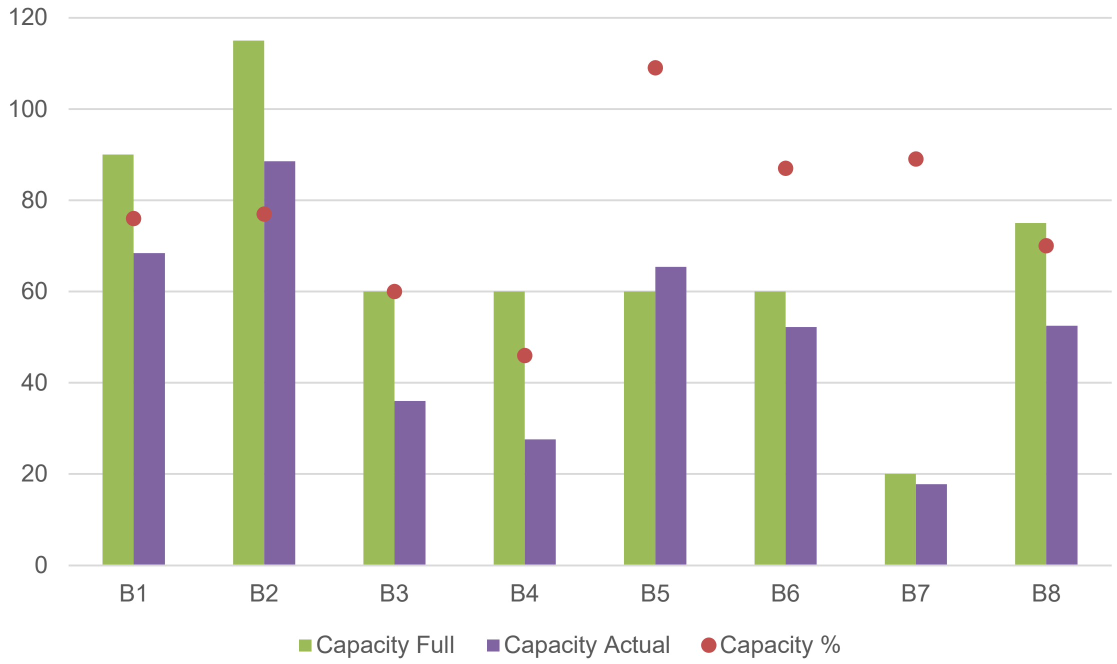

Figure 6. Capacity utilization in Finland.

5.5 Benchmarking loss in Finland

The costs of biogas plants consist of purchases of materials and services, personnel costs, and variable and fixed costs of maintenance and production, such as maintenance materials and consumables, water, sewerage, heating, electricity and production chemicals.

Biogas plant's main purchases of materials and services are shown in Figure 7.

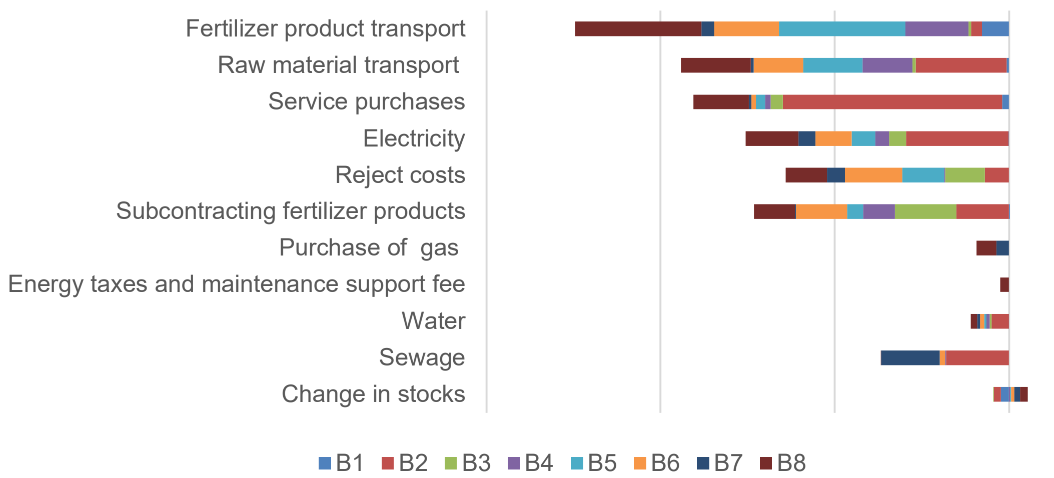

Figure 7. Materials and services in Finland.

It is easy to see from the Figure 5 that the largest costs for material and service purchases consist of transportation and disposal fees for fertilizer fraction and transportation of fertilizer and raw material. In addition, service purchases play a significant role in costs and especially at facility B2. The costs of electricity, chemicals and reject are also worth mentioning.

In Finland, biogas plants must pay special attention to the fact that the value of the stock is negative throughout the value chain. That is, stocks of digestate usually do not generate income, but are an expense item; though, in a few exceptional situations, the nutrient fraction has a positive value. For this reason, the stock must be treated in such a way that as more fertilizer fraction is stored in the stock, the negative value of the stock increases. And correspondingly, when the fertilizer fraction is removed from the stock, the negative value of the stock decreases. That is, the value of the stock is zero when there is no fertilizer in stock, but if fertilizer is formed, the value of the stock is negative.

Other operating costs of the plants are shown in Figure 8.

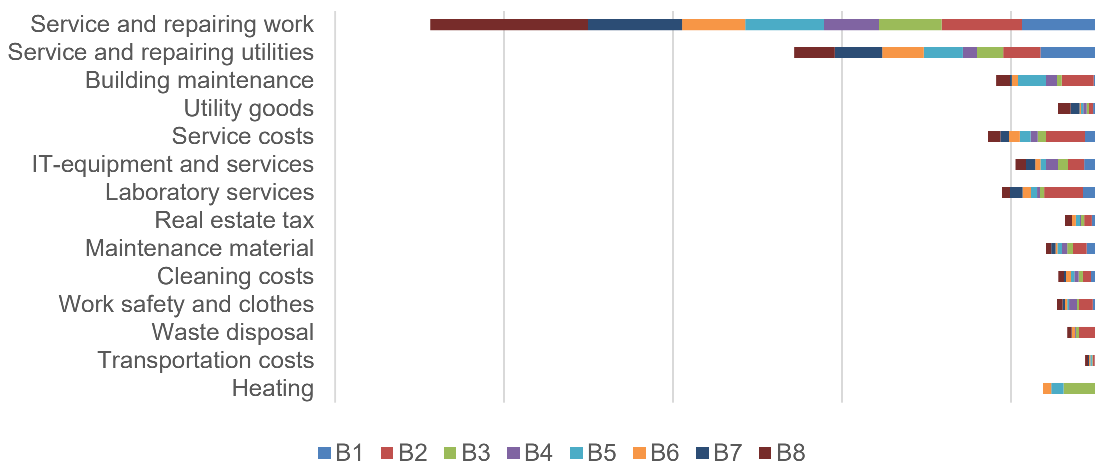

Figure 8. Other operating expenses in Finland.

It can be immediately seen from the figure 8 that the service and material and labor costs resulting from repairs cause the largest cost items. These maintenance costs are examined in more detail in Section 5.9.

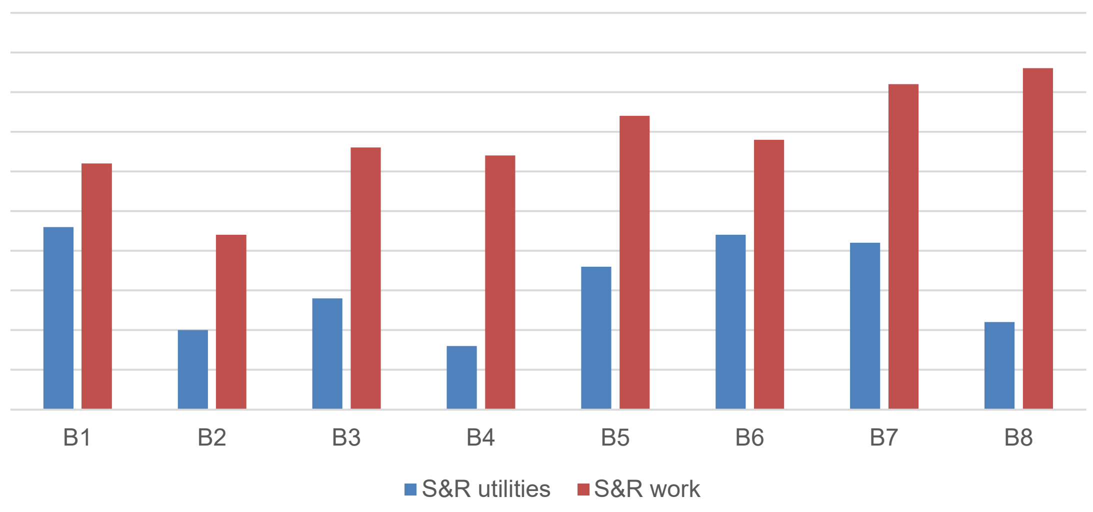

Figure 9. Service and repair utilities versus work.

Figure 9 shows the relationship between maintenance supplies and labor. In all plants the work has a higher cost than utilities.

This thesis does not delve into the department-specific cost items of the departments.

5.6 Case B1 biogas utilization

The high profitability of plant B1 was due to good sales of the waste treatment service, with the plant receiving only marginal income from biogas sales. This is due to the fact that the gas is utilized by a CHP unit for electricity and heat. Plant B1 does not receive production subsidies for electricity and heat, in addition, the maintenance costs of the CHP unit are very high. In practice, more than 50 % of the revenue from the sale of electricity and heat goes to the service and maintenance of the CHP unit. However, it should be noted that by producing electricity, the plant is allowed to purchase electricity tax-free, so even if the income from the use of CHP is not significant, savings can be made from tax-free electricity. Still, if the value of gas for clean production is calculated, the value of gas is only a few € / MWh. This is based on the sale of electricity and heat at plant B1, when production has been 27.6 GWh in 2020.

If the gas was purified the value of biogas could be easily multiplied. The operational costs for electricity, water, and spare parts in an upgraded plant B1 capable of purifying the gas based on water-scrubbing technology would come to approximately same per year as in service and maintenance of an CHP unit (according to Gasum PnL 2020 & Pulsa 2008, 32).

This results as revenue of significant increase with the biogas production of 27,6 GWh and the maintenance and operating cost are about 11 % of the total biogas sales.

5.7 Benchmarking profit in Sweden

At Swedish biogas plants, revenue comes mainly from biogas sales. On average, biogas sales generate 89 % of net sales. In Sweden, biogas is supported by production aid, which corresponds to an average of 30 % of the total turnover of these plants. Fertilizer sales account for an average of 7 % of total sales. Revenue ratios are shown in Figure 10.

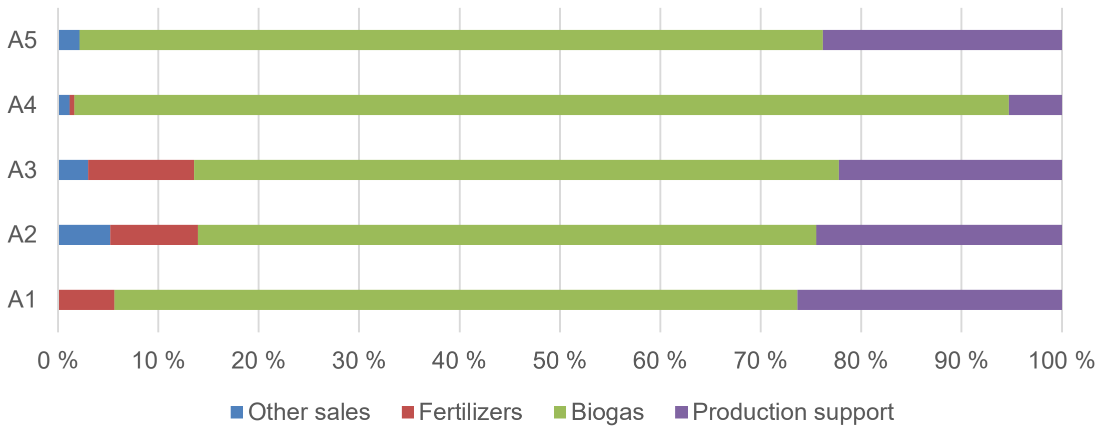

Figure 10. Revenue categories in Sweden.

Unlike in Finnish biogas plants, the plant's capacity is not in the same way a determining or process limiting factor. Swedish biogas plants aim to minimize costs in relation to the gas produced. As raw materials are purchased for plants, much attention is paid to the gas production potential of the raw material. Swedish biogas plants therefore aim to purchase raw materials with the highest possible gas production potential in order to maximize biogas production. For Swedish biogas plants, of course, maximum capacities can be calculated, which are generally technical maximum capacities.

A1

Plant A1 processes approximately 100,000 tons of raw materials annually and produces approximately 65 GWh of biogas. The biogas is purified by water scrubbing technology and pressurized, after which it is sold for liquefaction to a separate company. About 92 % of the plant's net sales come from gas sales. About 8 % of the plant's turnover comes from fertilizer sales. (Gasum, SWE production report)

The biogas plant's feedstock consists mainly of industrial wastes and food insdustry from the plant's surroundings. The plant also produces organically approved fertilizer.

A2

Plant A2 annually produces about 55 GWh of biogas from 50,000 tons of raw material. 82 % of the plant's turnover comes from gas sales and 12 % from fertilizer sales. (Gasum, SWE production report)

The plant's feedstock is from the food industry and agricultural feedstocks such as grass. The biogas produced is upgraded to vehicle quality gas wtih water scrubber techonology and transmitted via the gas pipeline network. The plant also produces organic fertilizer, which is approved for use in organic farming.

A3

Plant A3 produces about 30 GWh of biogas from 80,000 tons of raw materials. Biogas is purified by water scrubbing technology and pressurized into gas containers that are transported to the application, such as filling stations. 83 % of the plant's turnover comes from gas sales and 14% from fertilizer sales. (Gasum, SWE production report)

Plant A3 is a major farm plant for the co-digestion primarily of manure and agricultural and food industry waste and residues in the region. Most of the biofertilizer is organically approved and returned to local agriculture.

A4

Plant A4 is the largest plant in Sweden in terms of gas production. It produces 110 GWh of biogas annually, which is purified by water scrubbing technology and fed into the gas network. Plant A4 processes approximately 90,000 tons of raw materials annually. 93 % of the plant's net sales consist of gas sales and less than 1 % of fertilizer sales. (Gasum, SWE production report)

The plants uses locally produced green plant material and agricultural and food industry residues as feedstock. Plant A4 also produces biofertilizers that are organically approved for farming.

A5

Plant A5 produces about 30 GWh of biogas from 80,000 tons of raw materials. The biogas is purified by water washing technology and pressurized into the pipeline and utilized in the vicinity. 97 % of the plant's turnover comes from biogas sales. (Gasum, SWE production report)

Plant A5 is a co-digestion plant for manure and agricultural wastes from the neighborhood. The fertilizer from this plant is taken back to the farmers in the area.

5.8 Profits all together SWE

Figure 11 summarizes the percentage yield ratios of sales and EBITDA % of Swedish biogas plants.

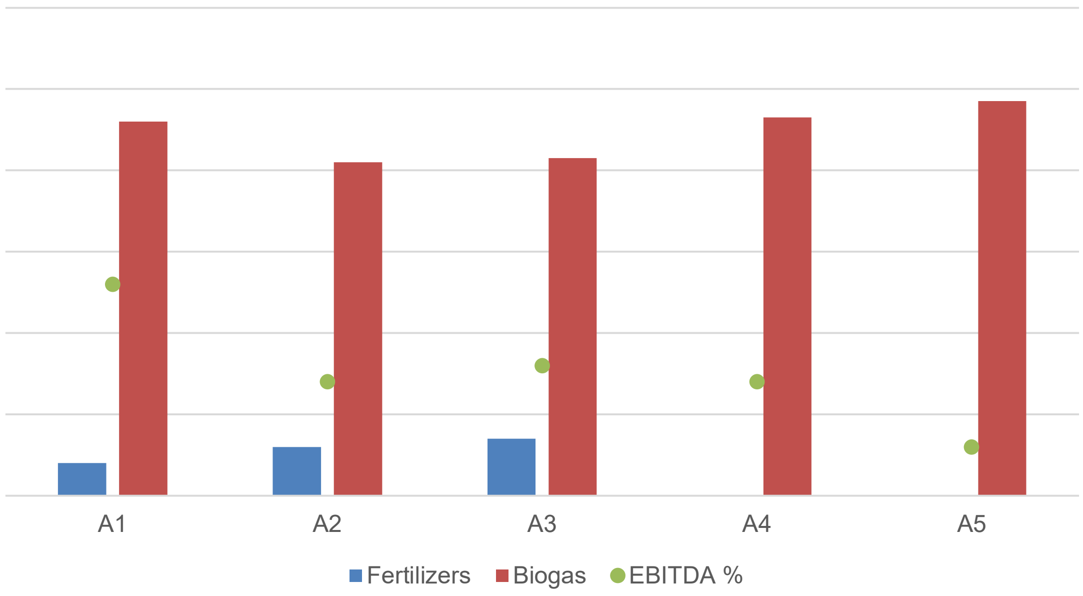

Figure 11. Fertilizer and biogas sales compared to EBITDA %.

The figure shows that the turnover of biogas sales is significantly higher than the sales of fertilizers. The turnover of biogas in each plant is between 80 and 97 %.

Figure 12 shows the ratio of biogas produced to EBITDA %.

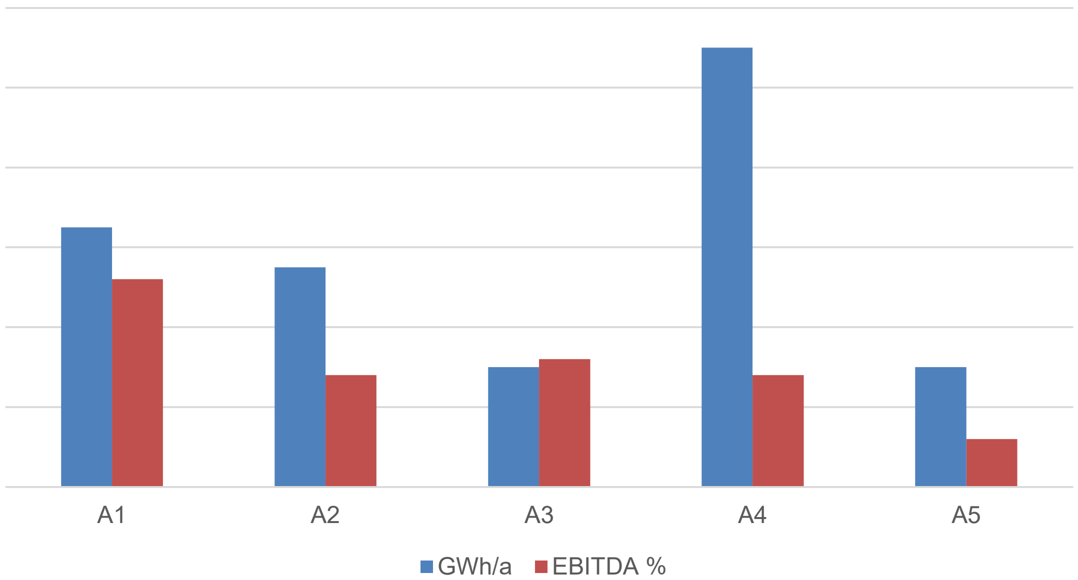

Figure 12. Biogas Production (GWh) and EBITDA %.

The most significant difference in EBITDA can be seen in plants A1 and A4. Plant A1 produces biogas with high EBITDA %, 65 GWh, while plant A4 produces with an average EBITDA % 110 GWh of biogas. Both plants have water scrubbing technology, but at plant A1 the gas is liquefied and at plant A4 the gas is fed into the local gas network. Plant A1 receives production aid corresponding to almost 39 % of the value of the biogas produced. Correspondingly, the production aid for plant A4 is only 6 %.

Plants A3 and A5 are of the same type and size in terms of gas production and raw materials, but the EBITDA % of plant A3 is significantly better than that of plant A5. Both plants receive production subsidies for the biogas equivalent to 35% and 32% of the value of the product gas, respectively. The difference of three percentage units alone does not explain the difference in profitability.

Plant A3 also receives revenue from the sale of fertilizers, but A5 does not. This corresponds to about 14 % of turnover. On the cost side, the most significant difference is seen in the raw material purchased. Plant A5 spends almost three times as much money on raw materials as Plant A3. The maintenance costs of plant A5 are also more than four times higher than plant A3. The losses are shown in Figure 13.

5.9 Benchmarking loss in Sweden

For Swedish biogas plants, the most significant cost is the purchase of raw materials. Otherwise, the costs are fairly evenly distributed between the transport of fertilizer preparations and raw materials, and the maintenance of the plant and the production electricity.

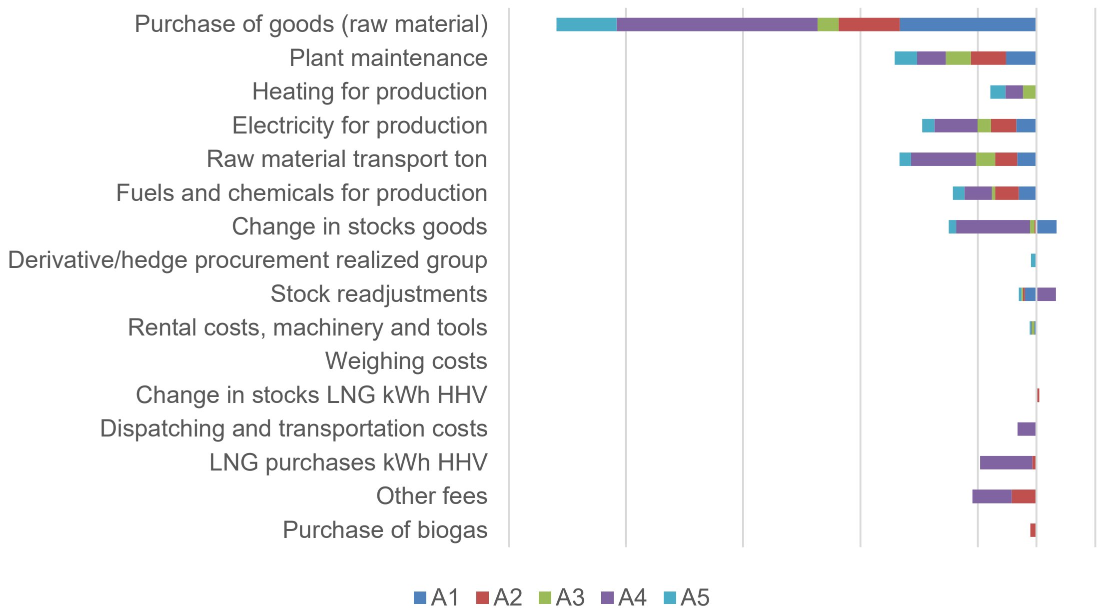

Figure 13. Materials and services in Sweden.

Figure 14 shows other production costs. The most significant costs arise from work permit and inspection fees, occupational safety materials and workwear, maintenance spare parts and materials, and maintenance purchase services.

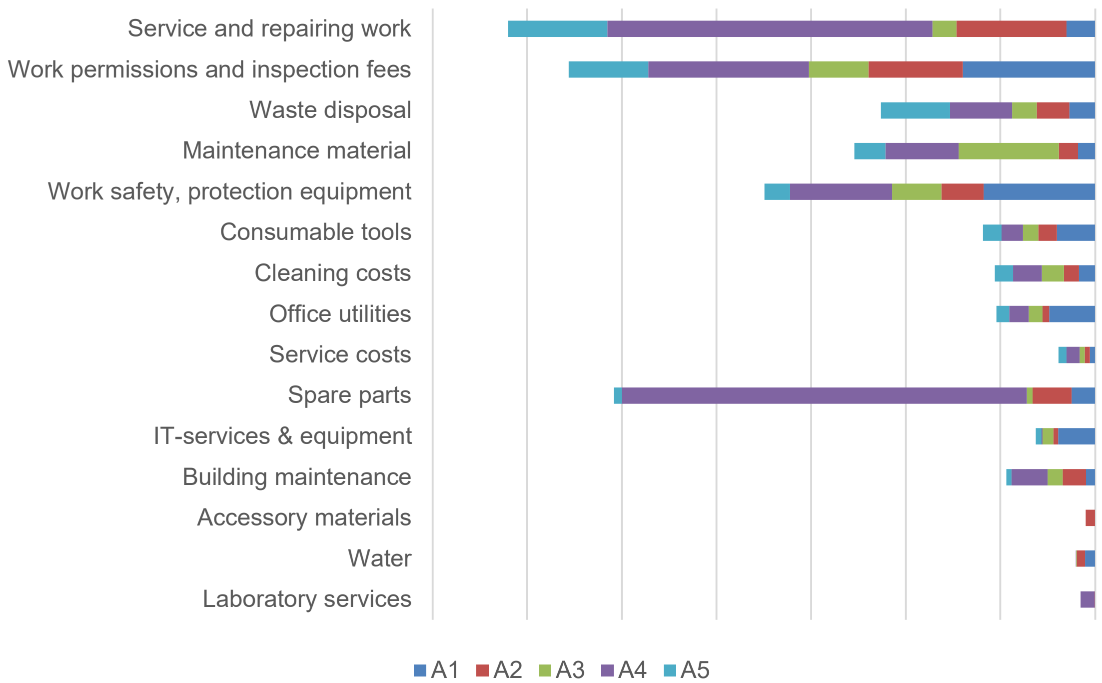

Figure 14. Other operating expenses in Sweden.

5.10 Comparing Finnish and Swedish biogas plants

A comparison of Swedish and Finnish biogas plants based on purely PnL proved to be challenging. The first problem is due to the incomplete financial data available and the fact that the entries in the accounts may be positive on the expenditure side and negative on the revenue side. For example, the sales account for gas production is accounted for as an expense account on a PnL sheet. In practice, this account is an income account from the perspective of the biogas plant, which should appear as a sales account, but it was incorrectly used as expenuditure account from Gasum Group perspective. An explanation was eventually found for all entries, but a lot of manual correction had to be done for these. Another problem is that there are differences in the use of accounts. For example, the recording of maintenance assets is done differently between countries.

The total turnover in Sweden and Finland is shown in Figure 15.

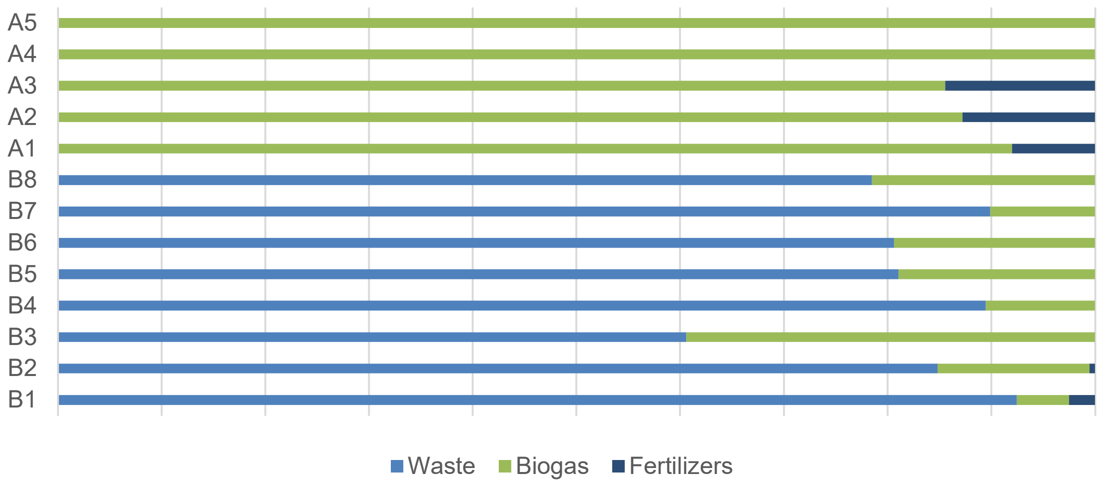

Figure 15. Sales by category in Finland and Sweden.

The total amount of biogas produced by the plants in Finland and Sweden is shown in Figure 16.

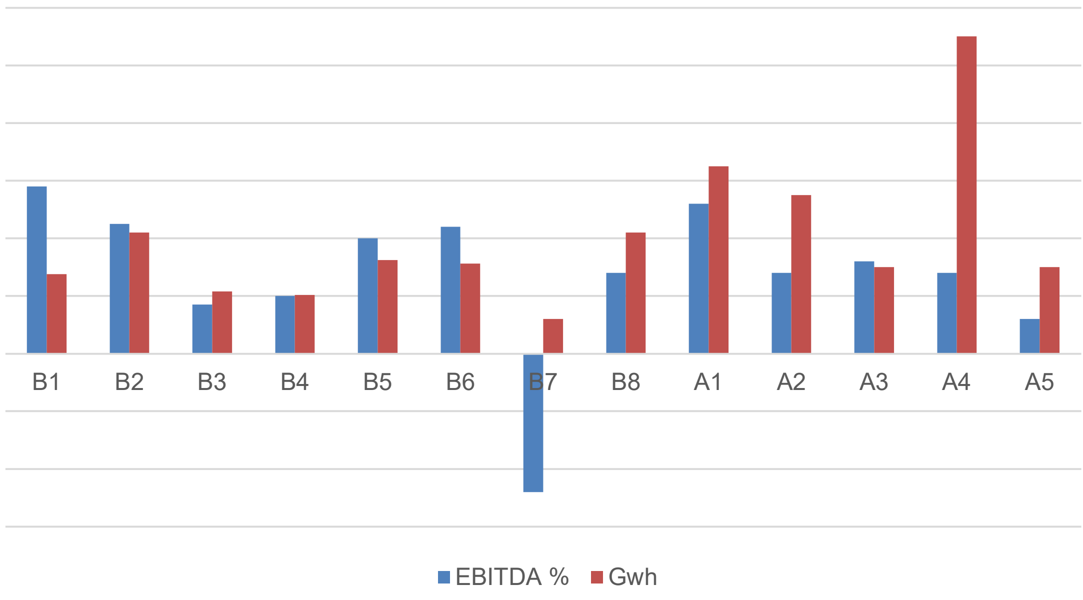

Figure 16. Biogas production and EBITDA % in Finland and Sweden.

In terms of costs, the comparison between the Finnish and Swedish biogas plants is shown in Figure 17. For the cost accounts, accounts that were the same for both countries were selected for comparison, although the logic of the plants' earnings is different.

The share of fuels or chemicals in production does not rise to a very significant position in any plant, nor does the share of electricity purchases. On the other hand, the costs of maintenance and fertilizer products are a very clear cost, and Finnish plants in particular can see that the costs of fertilizer products are very significant compared to Sweden.

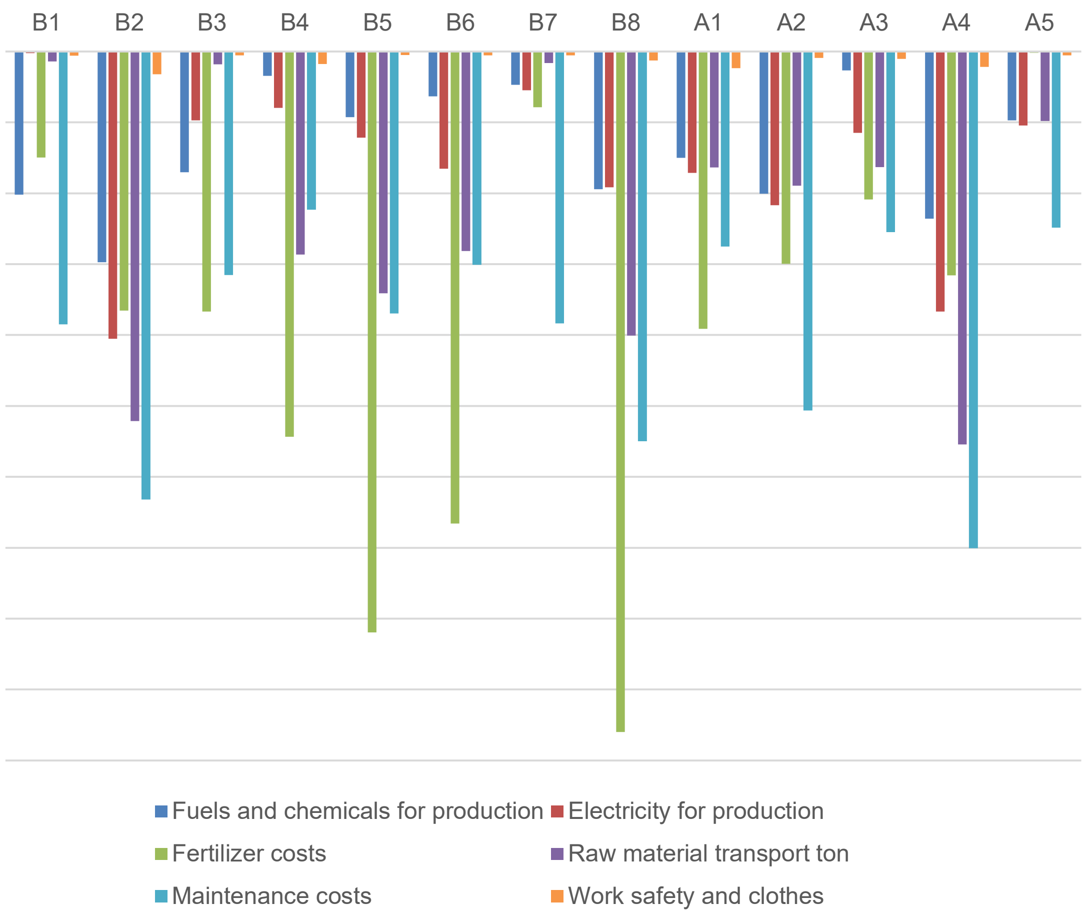

Figure 17. Main costs at biogas plants.

6 DEVELOPMENT OF COST-EFFECTIVENESS

For biogas plants, both in Finland and Sweden, a few development targets have been identified that would improve the plants' turnover and cost-efficiency factors. For some of the identified factors affecting efficiency, more research should be done to ascertain the reasons for the inefficiency or lack of cost-effectivess. In particular, harmonization of accounting for both countries would be a significant improvement. Consistent accounting would allow for better comparisons and could open up new cost-effectiveness drivers.

6.1 Processes to improve

In the case of Finnish biogas plants, revenue would generally be improved by a high utilization rate for the plants, a good sales price for biogas and a good low-cost disposal of the fertilizer products.

The profitability of Finnish plants could be further investigated by calculating the price at which it is worthwhile to take more raw materials into the plant, so that the gate fee received would cover the production costs, but generate more turnover from the produced gas. It would make sense to carry out this study, especially for plants with currently below average utilization rates.

In addition, a more detailed calculation should be made for plant B1 to change the gas utilization so that the CHP unit would be abandoned and the biogas would be upgrated for transport use.

Also, in plants where the cost of disposing of a fertilizer product is high, the processes for handling fertilizer products should be developed in such a way as to reduce costs. Gasum is already preparing investments in some of these plants.

The challenge for Swedish biogas plants is that there is currently an oversupply of biogas. Demand for CBG in Sweden is declining in traffic use, but demand for LBG for heavy duty vehicles and, correspondingly, demand by maritime traffic is increasing. In the case of Swedish plants, the construction of a joint liquefaction plant in a key area could be explored, so that the purified biogas would be transported for liquefaction to the liquefaction plant, from where it could be passed on as a higher value chain product.

Swedish biogas production in particular is already being disrupted by production in other countries with higher production subsidies. The high production subsidy model distorts the real market value of biogas and in practice leads to the point where operator with the highest production subsidy being able to sell cheaper biogas and its profitability is based more on state aid than on actually covering production costs (Westman, 2017). This distorts competition. A possible distortion of the competitive situation is also possible in Finland in the future.

The price produced for gas produced in both countries should be as high as possible and the gas produced should not be lost. Gasum commissioned an Operational Excellence project from an external consultant to study improving the performance of biogas plants. One factor identified was minimizing gas flaring. Other areas of development were maximizing and stabilizing gas demand. In general, the study also identified the need to develop and clarify Gasum's strategic and operational performance management, including the development and harmonization of the maintenance business model, data management, increased collaboration between plants, continuous fluctuations in production and demand, poor value of fertilizers and lack of continuous improvement - to name a few (Gasum OpEx report, 4). The identified developments are shown in Figure 1.

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Figure 18. Gasum Biogas operations.

Similarly, the OpEx report found that larger capacity biogas plants offer a higher EBITDA % than smaller biogas plants. According to the report, the limit for turnover in Finnish plants is about 2 million euros and in Swedish plants about 4 million euros.

In particular, a model should be created for Swedish biogas plants that takes into account the potential for gas production in raw material pricing. That is, a raw material with a higher gas production potential is paid more than a raw material from which no equivalent amount of biogas can be produced. Of course, it must be kept in mind that the overall availability of raw materials and, at some point, the raw material with a lower gas production potential may have to be taken in order for the plant in general to run.

6.2 KPI’s

Fully uniform KPI values have not yet been created for the biogas plants and, in some cases, they are very difficult to create at present, due to incomplete financial data from the plants or different ways of recording them. However, Gasum has already started defining KPI values, but they should be further developed to ensure that the data behind the KPI is valid.

However, a few KPI values are already identifiable that could be considered as preliminary indicators in determining cost-effectiveness. Such indicators have already been presented in previous charts and some of them are already reported and monitored on a daily basis. Examples of such KPIs include utilization of biogas plant production capacity, EBITDA %, gas production volume, raw material price per turnover, biogas production per raw material ton, maintenance cost per raw material ton and maintenance cost per produced biogas.

In addition, internal KPI values for maintenance should be clarified. For example, what percentage of maintenance events is preventive maintenance and what percentage is corrective maintenance. Reducing the share of corrective maintenance can reduce unexpected production interruptions that increase plant utilization and ensure high and continuous gas production.

6.3 Development of capacity and biogas utilization

Two key factors are to strive to utilize the maximum capacity of each plant and the gas produced. Plants should therefore operate close to their maximum capacity and produce as much biogas as possible. In addition, biogas should be as profitable as possible and should not be flared at all. In order to make this possible, attention must be paid to the timely logistics of the raw material and the high gas production potential. In addition, maintenance processes must be developed to minimize unexpected production interruptions. This essentially involves creating and harmonizing a maintenance strategy. This work has already started at Gasum from the beginning of 2021. An integrated maintenance strategy enables, among other things, the sharing of spare parts between plants, the sharing of information to solve problem situations and the finding of maintenance partners.

According to the OpEx report, full utilization of the gas would enable an additional several million euros in turnover. Developing maintenance and learning from other institutions so that the best possible way of working can be found can generate savings few million euros.

7 DISCUSSION

The profitability and cost-effectiveness of biogas plants as a whole consisting of a few separate factors, which is not quite simple to balance. Inside Gasum, there is already talk of a “biogas triangle” which means a balance between raw materials, fertilizer products and biogas. Balancing the biogas triangle allows for cost-effectiveness because optimizing one part interferes with the other vertices of the triangle. The biogas triangle is shown in Figure 19.

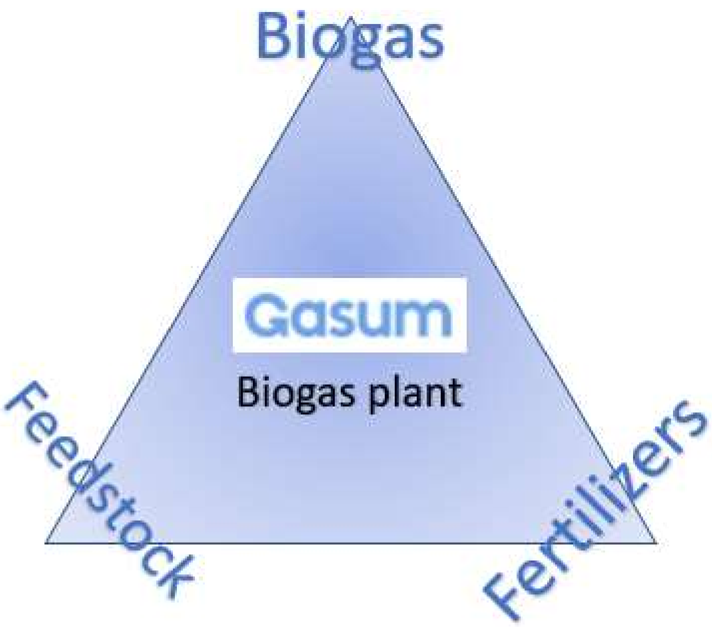

Figure 19. Biogas triangle.

Optimizing the biogas triangle seeks to form the largest possible triangle so that the ratio of the apex of the triangle remains optimal. It is therefore a matter of obtaining raw materials for the plant in a cost-effective manner, optimizing the biogas produced under process conditions and minimizing production interruptions, and cost-effective further processing or further utilization of fertilizer products.

The location of the biogas plant is then of great importance. If a biogas plant can be built in an area where raw materials are well available nearby and cheaply, and there is an immediate and good market for gas and efficient further utilization of fertilizers, there is a high chance of cost-effectiveness of the biogas plant. For existing plants, optimization should be examined from the same basic principles.

The plant must be provided with raw materials with high gas production potential at a good price, so that the production of biogas is as high as possible and the biogas should be sold at the best possible price. In some cases, it may mean selling gas as raw gas if a user is found, and in other cases, further processing and transportation of the gas to achieve a higher value chain. And finally, the value of the fertilizer should also be obtained, either the lowest possible cost of disposal or, through processing, sales value for Finland or the highest possible value for the fertilizer for Sweden.

7.1 Reflection

The thesis partially found answers to the research question, is the cost - effectiveness of biogas plants with higher operating capacity better than that of smaller plants with smaller operating capacity? As well as auxiliary questions: What are the main features to have an impact on cost-effectiveness? Which technical choices in the operation of a biogas plant affect cost-effectivess?

It can be concluded from the study that the cost-effectiveness of a biogas plant is proportional to the capacity of the plant. And the larger the plant, the more profitable it is in the size classes studied. It is therefore a matter of economies of scale in so far as the balance of the biogas triangle is maintained. The profitability and cost-effectiveness of the plant can be optimized in terms of technical solutions. One clear example of this is the example of plant B1 in gas recovery. Otherwise, for technical choices to increase cost-effectiveness, less clear examples of plant network could be found that could increase cost-effectiviness.

7.2 Usefulness and reliability

The usability and reliability of the thesis largely depends on the reliability of the basic data. As mentioned earlier, the PnL data was fragmented and in part the data had to be combined to calculate the desired reference values. It is possible that the baseline data itself distorts the study, but on a large scale, the results are reliable. Reliability is enhanced by expert interviews that suggest the same results as the results of the thesis.

Some of the results were, so to speak, “self-evident,” such as increasing sales to get more revenue. However, it is good to note from which sources the turnover is most available and where there is the most potential. In addition, it needs to be clarified that while the full utilization of the biogas produced, rather than flaring, is also self-evident, it is important to clarify its impact on the overall economy.

The most significant potential would be the observation of how much the profitability of plant B1 can be increased by making the best use of the biogas produced.

7.3 Next steps

Cost-effectiveness, and in particular the profitability of technical investments, could be examined from many different perspectives. For plants that do not have a processing technology for the fertilizer product, the minimum capacity of the plant could be studied and determined, which would allow the investment of the processing technology with an acceptable payback period. However, Finnish biogas plants also have value for fertilizer preparations, as long as the quality of the fertilizer is sufficient for agriculture or industry.

In addition, the previously mentioned centralized biogas liquefaction unit for Swedish plants would be an interesting entity to study. A centralized liquefaction unit would allow the full capacity of Swedish biogas plants to be utilized and the gas would always be further processed without the need to worry about gas flaring. This assumption is, of course, based on the fact that gas demand will continue in liquefied form in the future in heavy transport, maritime transport and possibly industry. Liquefied biogas has a very positive market outlook due to its high energy density and can serve as a major weapon in the fight against climate change.

8 CONCLUSIONS

The cost-effectiveness of a biogas plant seems to be linked to the plant's capacity, regardless of whether the plant's earned logic is based on waste service sales or biogas sales-based, as is the difference between Finland and Sweden. The cost-effectiveness of the plant can be further affected by ensuring the highest possible capacity utilization rate. Thus, a plant with a higher operating capacity is more cost-effective than a plant with a lower operating capacity. Economies of scale also apply to biogas plants.

In addition to capacity, cost efficiency is significantly affected by the gate fee of the waste fraction treated in Finland and, to a lesser extent, the turnover from biogas. However, even in the case of Finland, the higher gas sales price is important for the overall economy of the plant. Thus, technological choices can improve the plant's profitability and cost-efficiency.

The price and quality of the raw material purchased in Sweden have a corresponding effect on the plant's overall economy, but gas turnover is more important. Furthermore, technical choices in biogas utilization can improve profitability and cost-effectiveness.

For both countries, transport costs for fertilizer fractions and raw materials, as well as maintenance costs, account for a large share of total costs. However, it is difficult to say on the basis of this study which technical choices can have a significant impact on cost-effectiveness.

And finally, the geographical location of the plant allows for the formation of an efficient biogas triangle, which further enables a cost-effective biogas plant.

These results can be used to increase the cost-effectiveness of some biogas plants of Gasum. For more detailed analysis a better accounting guide should be made, so that better KPI’s can be formed.

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