Organic Biogas in Denmark: Achieving Symbiosis between Farmers and Producers and Synergy with National Policy Goals

Ingeniørspeciale udarbejdet på basis af biogasprojekt om økologisk gødning fra afgassede faste biomasser

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Organic Biogas in Denmark: Achieving Symbiosis between Farmers and Producers and Synergy with National Policy Goals

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Master Thesis

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ABSTRACT

There are found to be a great need, for a solution that provides organic farmers with a greater availability of organic fertilizer. This is due to the goal of doubling the area with organic farming before 2020, and that fact that regulations are currently needed, in order to provide the organic farmers with the needed fertilizer. In addition to this, are biogas is expected to be a key factor in the achieving of the climate goals, of being independent from fossil fuels in 2050. During the degasification of biomasses in the production of biogas, is the fertilizing ability of the biomass massively improved, and therefor is the degasified biomass found interesting as fertilizer in organic farming. The question is, if a symbiosis between biogas plants and organic farmers can be created, in a manner that are profitable for both parties. The problem statement for this project is therefor to investigate, if the symbiosis between organic farmers and biogas plant can be made profitable for both parties. The approach for solving this problem statement, was to use a case study with three farmers found to be facing this problem. The case study is used in order to develop the needed knowledge through a literature review, which is used in order to conduct a business case on the case study. This business case is used in order to show the profitability in the symbiosis. The result from this study showed, that no profitability was found for the farmers in the symbiosis. It was found that the investor in a biogas plant, needs to be secured an annual return of investment, before being interested in investing in a project. Therefor is the symbiosis found to be profitable for the biogas plant, but not for the farmers. The conclusion to the project is therefor, that the symbiosis is not found profitable, but the cooperation is found to be able of supplying the farmers with some of the fertilizer needed.

1. PRELIMINARY ANALASIS

The preliminary analysis will contain an introduction to the problem that is found for this project. Following the introduction a short investigation into the two main areas of the project, organic agriculture and biogas production will be presented, followed by a description of the company that is the partner in the project. Based on the findings from these three sections a problem statement to the project will be created, determining the object of the continued investigations. Following the problem statement, the stakeholders and their interest to the project will be identified. The problem statement and stakeholders to the project will be the basis for the method, which are selected and described in the last section of this phase.

1.1 INTRODUCTION

The introduction will contain an analysis into the areas within climate and organic agriculture goals, which have led to the creation of this project. The introduction will end out, linking the goals from the two areas to each other, hereby developing a symbiosis between organic farming and biogas production.

1.1.1 Climate goals

The overall international climate goals are to reduce the pollution of greenhouse gasses, and promote the development of more sustainable ways of producing and using energy (United Nations, 1998) (Morgan, 2014). Reaching these goals should help stabilize, and later decrease, the concentration of greenhouse gases in the atmosphere (United Nations , 1992). These goals were developed and described in the Kyoto protocol (Oberthür & Ott, 1999), which was developed and signed by 192 parties (United Nations, 1998) (United Nations , 1992). The protocol was firstly taken into force in 2005, where 37 industrialized countries and the European Union (EU), committed themselves to binding targets (Cirman, Domadenik, Koman, & Redek, 2009) (Elzen, Höhne, & Vliet, 2009), towards reducing emission of greenhouse gases. The first target was to lower the level of emission of the greenhouse gases with five percent, compared to the level in 1990, in the timeframe 2008 to 2012 (Cirman, Domadenik, Koman, & Redek, 2009). The second target, and the current target, is to reduce the emission by 20 percent compared to the level in 1990, this within the timeframe 2012 to 2020 (Elzen, Höhne, & Vliet, 2009).
In order to reach these goals, EU developed an internal agreement in 2007 (European comission, 2008), hereby stating how the goals for 2020 in the Kyoto protocol (Oberthür & Ott, 1999) can be achieved. This was done in order for the countries in EU (European comission, 2008), to align the policies and strategies towards energy production, and climate initiatives. In order to reach the goals in 2020, three overall goals were made, called "20-20-20" targets;

- A 20 percent reduction in EU greenhouse gas emission from 1990 level
- Raising the share of EU energy consumption from renewable resources to 20 percent
- A 20 percent improvement in the EU´s energy efficiency

Beside the targets, it was agreed that all member states are obligated to submit National Energy Efficiency Action Plans (NEEAPs), to the European Commission (European Comission, 2011). In the NEEAPs, the national strategies and measurements toward achieving the "20-20-20" targets shall be described, in order for the European Commission to assess the development towards the target. It is agreed to develop three NEEAPs (2007, 2011 and 2014), in order to control the development towards the targets (European Comission, 2011).

Based on the NEEAPs, the Commission assesses the countries' ability to meet the targets, giving them requirements if the NEEAPs do not succeed in meeting the targets.

Denmark is as a member of EU, obligated to follow the targets and regulations from the two agreements (Kyoto and 20-20-20). The latest NEEAP for Denmark is from 2011 (Energi styrelsen, 2011), but the latest assessment of the NEEAP is from 2013 (Energy Efficiency Watch, 2013). The assessment shows that Denmark is on the right path of achieving the targets (Energy Efficiency Watch, 2013). The NEEAP for Denmark is based on the overall climate and energy action strategy for Denmark, which is to become independent from fossil fuels in 2050 (Danish Commission on Climate Change , 2011) (Energistyrelsen, 2014). The plan is called *"Energy strategy 2050 – from coal, oil and gas to green energy"* and is published by the Danish government, as an extension to the 20-20-20 targets from the EU.
The strategy states that a greater use of biomass is needed, and that a solid foundation for biogas expansion is needed (Danish Commission on Climate Change , 2011). Bring these two strategies in to action, will have the effect that agriculture will have to play a role, as a green energy supplier, in the transition to fossil fuel independence (Energi styrelsen, 2010). In order to promote biogas production, the European Commission accepted a proposal from the Danish government, in February 2014, allowing them to give funding to support operation and investment in biogas (Energistyrelsen, 2014). The use of biomass for electricity production was in 2009 at ten percent of the total amount of biomass produced, and is targeted to be at 20 percent in 2020 (Danish Commission on Climate Change , 2011). The support scheme is expected to help achieve the level of 20 percent in 2020 (Energistyrelsen, 2014).

In order to achieve the object that is for the agriculture to have a key role in the conversion to green energy, the Green Growth strategy was developed by the Danish government in 2009 (The Danish Goverment, 2009). One of the objectives in the green growth strategy is to use livestock manure to produce biogas (Energi styrelsen, 2010). The current use of livestock manure used for biogas production is at five percent of the total livestock manure available, but the target in the green growth strategy (The Danish Goverment, 2009) is to use 50 percent of the available livestock manure in 2020. In order to produce biogas at an optimal basis, the same amount of biomass from crops is needed (Energi styrelsen, 2010), leading to the fact that 6 percent of the agricultural land shall be used for producing the needed biomass (Uffe Jørgensen, 2013). Therefore it is expected that the market for crop biomass will develop over the following years (Copenhagen Economics, 2012). This makes it interesting to investigate the green growth strategy effect on agriculture.

1.1.2 Goals for organic farming

Another object in the green growth strategy is to create a framework that will enable the area for organic farming to double in 2020 (The Danish Goverment, 2009), hereby having 18.000 hectares per year to be converted from conventional to organic farming. However, the tendencies in Danish organic agriculture are not going towards more organic farming (Ministeriet for Fødevarer, Landbrug og Fiskeri, 2011), due to the lack of economic profitability in the organic production (DLBR Economy, 2011). The lack of economical profitability can be related to the low crop yield and low crop quality in organic agriculture (Woese, Lange, Boess, & Bögl, 1997) (Adam, 2001) (Cobb, et al., 1999), which makes organic farming unprofitable for the farmers. The low yield in organic farming is due to the low use of nitrogen fertilizer in organic farming (Andersen, 2011) (Biao, Xiaorong, Zhuhong, & Yaping, 2002), which is due to legislations against use of inorganic fertilizers (Ministry of Food, Agriculture and Fisheries, 2013) and a low availability of organic fertilizer (David, Jeuffroy, Laurent, Mangin, & Meynard, 2004). The only option, organic farmers have, in order to generate organic fertilizer, is to use catch crops in the crop rotation (Olsen, Mejnertsen, & Askegaard, 2012), but only a small amount of the needed fertilizer can be made this way. In addition, the method is found to have a bad impact on the economy for the farmers (Olsen, Mejnertsen, & Askegaard, 2012), due to the fact that the fields with catch crops are not generating any income to the farmers.

In order to give organic farmer greater availability of fertilizer, regulations have been developed (Ministeriet for Fødevare, Landbrug og Fiskeri, 2014), allowing the organic farmers to use an amount of conventional livestock manure as fertilizer in their crop production. However, the object of the regulation is to phase out the use of conventional fertilizer (Oelofse, Jensen, & Magid, 2013), allowing the farmers only use organic fertilizer in their production. The regulations and the low yield from only using organic fertilizer, has resulted in a dependency to the conventional livestock manure allowed to be used by the organic farmers (Oelofse, Jensen, & Magid, 2013) (Foissy & Vian, 2014). The fact that the regulations will be phased out in the future has resulted in an even greater demand for organic fertilizer. This greater demand has also given doubt whether the goals of doubling the area with organic agriculture in 2020 can be achieved (NaturErhvervstyrelsen, 2014) (Oelofse, Jensen, & Magid, 2013). The dependency on conventional livestock manure, and the fact that the regulations will be phased out in the future, have led to a focus on how organic fertilizer could become more available in the future.

1.1.3 The symbiosis between organic farming and biogas production

As found in the previous two sections, there are future goals and obstacles for both organic farming and biogas production. The fact that agriculture is expected to play a key role in the development of biogas production in Denmark is linking the two areas together. It is also a known fact that processing biomasses in a biogas plant, increases the fertilizing abilities in the degasified biomass (Møller, 2006) (Jørgensen P. J., Biogas - Green Energy, 2009), hereby making it an efficient fertilizer (Sørensen & Birkmose, Kvælstofudvaskning efter gødskning med afgasset gylle, 2002) (Birkmose, Hjort-Gregersen, & Stefanek, 2013). Based on these facts a symbiosis can be found in between the two areas, hereby getting the farmers a better fertilizer, while the biogas plants is getting the needed biomass to their production. This symbiosis is even more interesting for organic agriculture due to the lacking availability of organic fertilizer, which can be acquired through degasification of biomasses from their production. In this context it is of great interest to investigate the symbiosis between organic farmers and biogas plants, in order to find the important factors in the symbiosis in order to make it function and profitable for both parties. Furthermore, it is of great interest to analyze the synergy between the national policies and the symbiosis, in order to find the best possible support for the symbiosis.

1.2 BASIS UNDERSTANDING

This section will investigate and describe the main aspects of the two main areas in this thesis, organic farming and biogas production.

1.2.1 Organic agriculture

Organic farming is based on a range of principles (IFOAM, 2014) (Kirchmann, 1985), which shall be seen as ethical principles making inspirations towards actions. IFOAM have developed four principles for organic farming (IFOAM, 2014);

The health principle – Organic agriculture should maintain and improve the soil's, plants', animals', humans' and planet's health as an indivisible unit.

The organic principle – Organic agriculture should be built upon living ecological systems and circuits, interact with them, emulate them and help preserve them.

The righteousness principle – Organic agriculture should be built upon the relations that ensure righteousness, in terms of the shared environment and life opportunities.

The precautionary principle – Organic agriculture should be operated in a cautious and responsible way, in order to protect the health and well-being of existing and future generations.

These principals help define organic agriculture, not only as industry but also as a way of living and thinking. The principles, needs to be a part of a solution within any organic agriculture initiative (IFOAM, 2012). In order to make a common understanding and way of following the principles International Federation of Organic Agriculture Movements (IFOAM) have made a rapport about the norms for organic production and processing (IFOAM, 2012). The Danish government has made legislations and rules based on the norms from IFOAM, which is developed and enforced by the Ministry of Food, Agriculture and Fisheries. Each year the Ministry of Food, Agriculture and Fisheries develops a guidance manual on organic agriculture (Ministeriet for Fødevarer, Landbrug og Fiskeri, 2014), hereby explaining rules and legislations within the area. As found in the introduction, fertilizer is highly important issues within organic agriculture therefore will this area be further investigated in the following section. A way of preventing many of the difficulties that are found in organic farming, e.g. weed problems, pesticides and nutrient deficiency, crop rotation is also found to be highly important in organic agriculture (Olsen, Mejnertsen, & Askegaard, 2012). Therefore this is found to be the second area that is important to investigate in order to understand the basis of organic farming.

1.2.1.1 Fertilizer use in organic agriculture

To ensure a healthy environment is the legislations on the amount of fertilizer there must be used, related to the amount of nutrients the crops can uptake (Ministry of Food, Agriculture and Fisheries, 2013). The crop selected for a field, soil type, previous crop and irrigation is determining the amount of fertilizer allowed to use on a specific field. The general legislations (Ministeriet for Fødevare, Landbrug og Fiskeri, 2014) towards fertilizing in organic agriculture are to;

- Cultivate legumes and other plants for green manure
- Provide an appropriate crop rotation
- Ploughing manure from organic livestock in to the soil
- Ploughing other organic material in to the soil.

It is only allowed to use organic fertilizer in organic agriculture, unless the crop rotation and the organic manure, green fertilizer etc. are not enough to reach the allowed amount (Ministeriet for Fødevarer, Landbrug og Fiskeri, 2014). If this is the case, it is regulated, so that non-organic fertilizer is allowed to be used, if the Ministry of Food, Agriculture and Fisheries approve the fertilizer. The maximal amount allowed is, as in conventional agriculture, related to the factors in the fertilizer plant (Area, soil type, irrigation, previous crop and crop), with the maximal limit being 140 Kg N-tot per ha per year (Ministeriet for Fødevare, Landbrug og Fiskeri, 2014). The allowed alternative fertilizers and amount can be found in the guidance manual for agriculture (Ministeriet for Fødevarer, Landbrug og Fiskeri, 2014). The alternatives are mainly related to the use of non-organic manure from livestock, which also was identified as necessary for many organic farmers in the introduction. The current regulations are allowing 70 Kg N per. ha per year of non-organic fertilizer to be used (Ministeriet for Fødevarer, Landbrug og Fiskeri, 2014), withdrawing this amount from the total amount of 140 Kg N per. ha per year.

1.2.1.2 Crop rotation in organic agriculture

It is found that crop rotation is essential, which also is verified by the fact that crop rotation is important in relation to fertilizer use in organic agriculture. A crop rotation is a structured system of planting crops sequent in the same area over an interval of time (Santon, Michelon, Arenales, & Santos, 2008). The use of a suitable crop rotation allows nutrients to recycle in the production in a natural relation with nature (Økologisk Landsforening, 2012). Hereby it is not only important to select crops based on the sales options, but to select the crops in relation to their role in the nutrient recycling, fields ecosystem, exploitation of fertilizer, pest and weed pressure and the ground-hugging methods possible (Økologisk Landsforening, 2012) (Zander & Bachinger, 2006). Crop selection and the way of rotating the crops, is therefore found to be highly important in organic agriculture, especially for farmers with only crop production (Watson, Atkinson, Gosling, Jackson, & Rayns, 2002) (Økologisk Landsforening, 2012). The important issue for the crop producers is to have a well-balanced relation between the crops and the nitrogen fixation from the green fertilizer and the catch crops, especially when only a small amount of fertilizer is available, where the level of competition with pest and weed is found to be high (Økologisk Landsforening, 2012). There are many methods of determining crop rotation (Økologisk Landsforening, 2012) (Zander & Bachinger, 2006) (Santon, Michelon, Arenales, & Santos, 2008), but common for all the methods is that the economy in the rotation will be the essential factor for selecting a certain crop rotation. This is due to the relation, which it will have on the yield and food quality in the crops, and hereby the earnings available from the yield.

1.2.2 The biogas production

The main content in biogas is methane (CH4) and Carbon dioxide (CO2), which is produced through anaerobic bacterial decomposition of organic compounds, in other words decomposition without oxygen (Mattocks, 2002) (Holm-Nielsen, Seadi, & Oleskowicz-Popiel, 2009). The gasses generated are a waste product of the respiration of these decomposer microorganisms, and the content of gas is determined by the composition of the substances that are being decomposed (Jørgensen P. J., Biogas - Green Energy, 2009). The decomposition of the three organic matters can be seen in figure 1 – *Decomposition of proteins, carbohydrates and fats*. The flammable part of biogas, hereby also the part containing energy, is the methane and the small amount of hydrogen that can be found in the biogas. The gases that are found in biogas can be seen in table 1 – *Gas content in biogas* below.

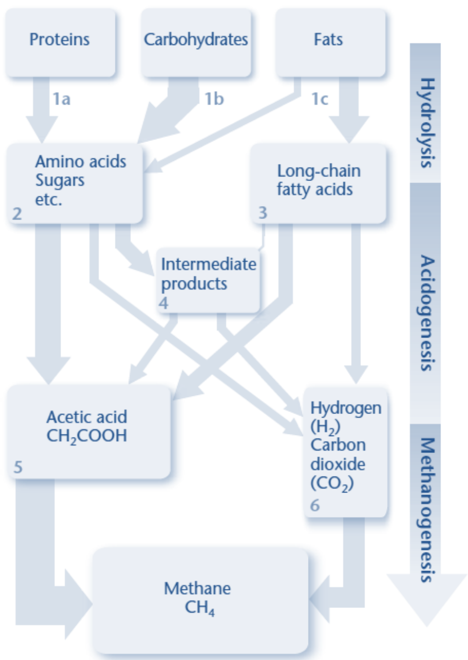


Figure 1 - Decomposition of Proteins, Carbohydrates and Fats

Gas	%
Methane (CH_4)	55 – 70
Carbon dioxide (CO_2)	30 – 45
Hydrogen (H_2)	1 – 2
Carbon monoxide (CO)	Traces
Nitrogen (N_2)	Traces
Oxygen (O_2)	Traces
Hydrogen sulphide (H_2S)	Traces

Table 1 - Gas content in biogas (Jørgensen P. J., Biogas - Green Energy, 2009)

The process of biological decomposition, from organic substances to methane and carbon dioxide in anaerobic conditions is highly complex. The process is done through the interaction between ranges of bacteria, which each have a part in the process (Jørgensen P. J., Biogas - Green Energy, 2009). The trash from one bacterium is the feedstock for the next bacteria, and the bacteria are therefore dependent on each other. In the next three sections, each of the steps will be explained further based on literature from Jørgensen (Jørgensen P. J., Biogas - Green Energy, 2009) and Artanti et al. (Artanti, Saputro, & Budiyono, 2012).

Hydrolysis

On this step, the high-molecular substances are degraded, which are polymers of protein, carbohydrates and fats that are tuned in to low molecular substances (monomers). A specialized bacterium delivers a range of specific enzymes that catalyzes the degradation. Lignin that is the main constituent of plant cell walls (5 – 40 percent[1]) cannot be degraded in an anaerobe process. Cellulose and hemicellulose that is a polymer composed of a range of sugar substances, is found to be complicated carbohydrates. These complicated carbohydrates can in principle be relatively easy hydrolyzed by the specialized bacteria found in the process, but in the plant tissue where these two are found, they are bound with lignin, which means that these carbohydrates are hard to hydrolyze.

Acid generation – Fermentation

The second process in the decomposition is in general called fermentation, rather than acidogenesis. In the process monomers (glucose, xylose, amino acids) and the long chain fatty acids (LCFA) are converted to acetic acid (CH_3COOH). A percent of this is degraded to carbon dioxide (CO_2) and hydrogen (H_2), while the remaining fraction is degraded into other short-chain fatty acids than acetic acid. These are also called volatile fatty acids (VFA). The difference between LCFA´s and VFA´s is the content of C-atoms in the fatty acids. Hydrolysis of fats results in LCFA´s, and therefore a great amount of these LCFA in the substance, while hydrolysis of protein results in VFA´s, and therefore a great amount of VFA´s in the substance. The balance between the LCFA´s and the VFA´s is an important factor for the process, and an imbalance can result in an inhibition of the biogas process.

Methane formation

The methanogenic bacteria or methanogens conducts the final step in methane formation. Two different groups of methane bacteria are conducting the methane formation. The one group is degrading the acetic acid (CH_3COOH) to methane (CH_4) and the other group is converting carbon dioxide (CO_2) and hydrogen (H_2) into methane (CH_4). In a normal process is 70 percent of the biogas production from acetic acids, while the last 30 percent comes from carbon dioxide and hydrogen. The methane bacterium is the bacterium with the

[1] Based on where in the growth process the plant is (Buranov & Mazza, 2008)

slowest growth rate in the entire process, and it therefore becomes the limiting factor in how fast the process can be conducted, and how much material that can be processed.

1.2.2.1 The biogas plant

In order to understand the biogas plant, there is a need for understanding how a biogas plant functions. The process conducted in the biogas plants is the anaerobic digestion as it is described in the section above. There is a range of different types of biogas plants that can bio used in order to conduct the process. The type of plant needed is determined by the biomass that is to be used in the production of biogas. The type of plants is regularly placed into two groups, wet anaerobic digestion (Leeuwenhoek, 1995) and dry anaerobic digestion (Radwan, Sebak, Mitry, El-Zanati, & Hamad, 1993). The great difference between the two plants is the way of handling the biomass in the process. For wet anaerobic digestion the biomass needs to be fluid so that it can be pumped between the different steps of the degasification process (Leeuwenhoek, 1995). In dry anaerobic digestion the biomasses, primarily plant and waste material, are processed in the form they are, not adding any fluid or other substances (Radwan, Sebak, Mitry, El-Zanati, & Hamad, 1993). This is not needed due to the fact that the biomasses are not pumped during the degasification process. The most common type of plant that is used is the wet anaerobic digestion plants (Jørgensen P. J., Biogas - Green Energy, 2009) (Mattocks, 2002). This is due to the fact that most plants are using slurry or sludge as the primary biomass in the plants, hereby making the biomass pumpable in the degasification process (Walla & Schneeberger, 2008). Dry anaerobic digestion plants are not as common, and are primarily used in to extract biogas from waste products. In figure 2 – *wet anaerobic digestion* a wet anaerobic biogas plant can be seen, in figure 3 – *Dry anaerobic digestion* a dry anaerobic biogas plants can be seen.

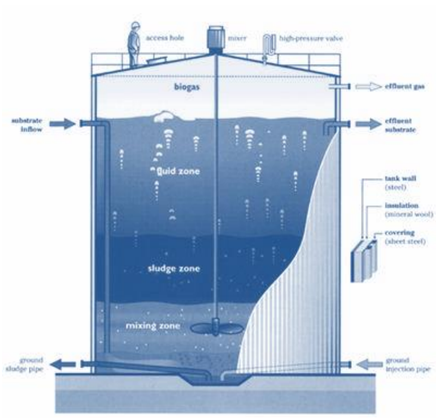


Figure 2- Wet anaerobic digestion (U.S. Department of Energy, 2014)

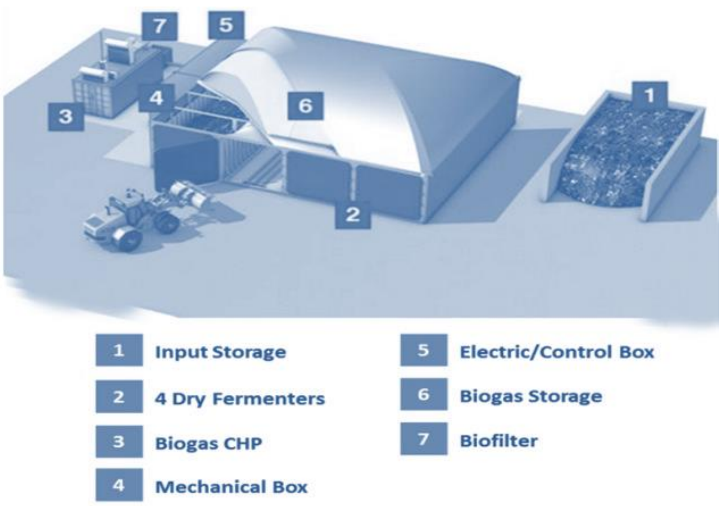


Figure 3 - Dry anaerobic digestion (Waste Management World, 2013)

General for both plants are that they have a reactor tank where the fermentation and methane formation are conducted. For wet anaerobic plants all three processes can be conducted in the reactor tank, whereas the hydrolysis is conducted in a different tank in a dry anaerobic digestion plant.

1.3 DESCRIPTION OF KNOWLEDGE CENTRE FOR AGRICULTURE P/S

The object of the knowledge center is to make the newest knowledge and technologies available, for the Danish farmers, in order for them to be able to produce world class food. This task is done by acquiring new knowledge from sources all over the world, processing the knowledge, in order to make it fit to Danish conditions, and communicate it to the farmers and their local advisors. Therefore, the customers to the knowledge center are both the farmers, and the local advisories. The local advisories are used in order to distribute the knowledge to the local farmers. The unique two-level advisory system is owned and used by the Danish farmers.

The knowledge center is located in Aarhus, occupying approximately 500 employees, in all areas related to agriculture (Knowledge centre for Agriculture, 2013). The knowledge center is a part of Danish Agriculture Advisory Service (DAAS), which is a partnership between 30 local advisory centers, and the knowledge center. In the partnership, DAAS is occupying approximately 2.500 employees, making it the biggest consulting firm in Denmark, and one of the leading agriculture advisors in Europe.

The keyword for DAAS is “impartiality”, meaning that the end customer shall by confident towards the knowledge delivered, knowing that the knowledge is independent of commercial and political interests. It is therefore essential, that the knowledge center is focusing on handling the interests of the customers, delivering knowledge based on a professional and impartial basis. In order to do this, the knowledge center has close cooperation with universities, ministries and interest organizations.

The following presents the mission, vision and values in Knowledge center for Agriculture (Konwledge centre for Agriculture , 2014). The researcher has as object to follow these statements in the investigation and result of this project.

Mission

“Our mission is to be a key driver in the development of a diverse and competitive agriculture”

Vission

“Knowledge Centre for Agriculture, should be a knowledge accelerator and unique in turning knowledge into business”

Values

“Be first, trustworthy and result oriented”

1.3.1 Departments

As described in the introduction, this project is concerning the areas of organic farming and bioenergy. This section is describing the organic farming department and the bioenergy department at the Knowledge Centre of Agriculture.

1.3.1.1 Organic farming

The organic department is occupying 14 employees at the knowledge center, and distributing the knowledge to 70 – 80 organic consultants at the local advisory centers (Knowledge centre of Agriculture, 2014). In cooperation with the local advisories, they deliver knowledge and service to approximately 3.000 organic farmers, and their 180.000 hectares (Knowledge centre for Agriculture, 2013). The object of the department is to widen the production of organic products in Denmark, by discovering ways of making organic farming profitable.

1.3.1.2 Bioenergy

The department is a sup-department of the crop production department, and is occupying five employees (Knowledge centre of Agriculture , 2014). The department is established in order to investigate and increase the production of energy based on the great potential that is found in the agriculture industry. The object of this is to reduce the environmental impact, by lowering the pollution of the greenhouse gases methane and nitrous oxide. The plan for achieving this object is to develop bioenergy production to be a separate line of production, which is contributing to the farmer's earnings.
In order to deliver the needed knowledge to the farmers, the bioenergy department is working in a multidisciplinary manner, using knowledge from the other department in order to investigate and develop the production of bioenergy. The sup-department is therefore dependent on the cooperation with the other departments within the knowledge center.

In the following work in this project, Knowledge Centre for Agriculture will be referred to as VFL.

1.4 PROBLEM STATEMENT

As stated in the introduction a symbiosis between organic farming and biogas production, in order to obtain the goals stated for these two areas. The symbioses between the two parties are also found interesting from VFL, due to a current focus on the area in the organic and bioenergy department. VFL is, as knowledge center for agriculture, a factor in the obtaining of the 2020 goals stated for organic farming, but also for the climate goals due to the link between the two areas. VFL wants to investigate the symbiosis that could be made, between a biogas plant and organic farmers, hereby producing biogas and fertilizer based on primarily crops from organic farms. In order to investigate the symbiosis, VFL has launched a project called *"Organic fertilizer based on solid organic material treated in a biogas plant"*[2]. The project's object is to investigate how organic farmers can cooperate with biogas plants, in order to make organic fertilizer more available. The overall object of their project is to find better economy in organic farming, hereby making it easier for conventional farmers to convert into organic production. This is due to the greater profit that is found, caused by the greater availability of organic fertilizer.

[2] Appendix 1 - Project description VFL

At the moment only one farmer in Denmark has an organic biogas plant in Denmark[3], even though the fertilizing improvements through degasification are well known, as it was found in the introduction. The hypothesis from VFL is:

"There are low degree of profitable economy in an organic biogas plant, especially if the primarily biomass is plant material"[4]

This project strives to answer the hypothesis from VFL, hereby investigating the profitability in the symbiosis between a biogas plant and organic farmers. A precondition to this project is therefore that the fertilizer output from the biogas plant is rated as 100 percent organic. In order to get a common understanding of the symbiosis, the symbiosis is defined in the following:

The basic idea of the symbiosis

The idea with the symbiosis is to use the biomasses that can be found in the organic farmer's crop rotation in a biogas plant. The degasification of the biomasses will generate an output of biogas from the biogas process, and increase the fertilizer quality in the degasified biomass. The degasified biomass is hereafter given back to the farmer in order to be used as fertilizer in their crop production. The biogas is sold in order to generate profit for the biogas plant, and degasified biomass as fertilizer will generate a higher crop yield, and quality, in the crop production at the organic farmers, hereby generating an extra profit. The two parties in the symbiosis will share the costs involved with the cooperation between the two parties. This is done using a not predefined cost distribution key. The symbiosis is therefore divided into three main areas, which can be seen in figure 4 – *The main areas in the symbiosis*.

The organic farmers

- The organic farmers are growing the crops that should be used for biogas production. Their object in the cooperation is to receive the biomass back after degasification, and generate a profit from the fertilizing ability in the degasified biomass.

The biogas plant

- The biogas plant is utilizing the biogas potential in the biomasses that are produced by the farmers. Their object in the cooperation is to produce biogas from the biomasses, hereby creating profit.

The symbiosis

- The symbiosis is all the cost and administration there is in the cooperation between the organic farmers and biogas plant. The object with the symbiosis is to keep the cost low, and distribute the cost from it in a way that makes the cooperation between the two parties profitable for both.

Figure 4 - The three main areas in the symbiosis

The object of this project is to investigate the symbiosis based on a case study, in order to find if a profitable symbiosis can be made between organic farmers and biogas plants. This

[3] Owned by Bjarne Viller – http://www.okologi.dk/landmand_/fagomraader/oekologisk-biogas/kompetencecenter-for-oekologisk-biogas/artikler-og-faglig-viden/oekologisk-biogas-bording.aspx

[4] Conversation with Erik Fog at VFL – Appendix 4 – Interviews/conversations

will include collection of plant offers from manufactures, in order to calculate the economy for the biogas plant. Another object in this project will be to identify the difficulties in the development of organic biogas plant, hereby finding the barriers that are the reasons for the low number of organic biogas plants in Denmark. This will be used in order to find the synergy towards the national political interest towards organic farming and biogas. The findings throughout this phase have led to the research questions that can be found in the following phase.

1.4.1 Research question

Following the questions that need to be answered in this thesis will be presented in a main question and supporting sup-questions.

Main research question

"Can organic biogas become mutually profitable for organic farmers and for commercial biogas suppliers in Denmark?"

SQ1: "How can cooperation with organic biogas be made profitable for organic farmers?"

SQ2: "What is needed in order to make the symbiosis interesting for commercial biogas producers?"

SQ3: "How can organic biogas be synergized with Danish national policies?"

1.4.2 Delimitation

This section describes the main delimitations there is found in this research. The delimitation is described in order to structure and structure the further research, hereby answering the main question. The delimitations to the project are presented in an unstructured manner in the following bullets.

- The research is delimitated to Denmark, and the possibilities for developing the symbiosis in Denmark. This is selected due to the fact, that the organic and climate goals the project is based on are the stated by the national policies in Denmark. Therefor is it not expected that the result of this project will be applicable for other countries. Furthermore is it found necessary to delimitate the investigation to one country, due to fact that each country has its own energy policy and laws, which makes it impossible to answer whether the symbiosis would work generically.

- The research on organic agriculture and organic farmers will be based on the precondition, that the organic agriculture is producing 100 percent organic. This is selecting knowing that there is a three year conversion phases, going from conventional into organic farming. This phase is relevant in order to achieve the goal of doubling the area with organic farming in 2020. But due to the fact that the conversion is conducted over a short period of time, will the conversion not be found relevant in this study. It is therefore found as a precondition to the research, that the organic farmers are operating a well-functioning organic crop production.

- The research has simplified the calculations of biogas output from biomasses. This is done due to the great complexity in calculating the exact biogas output, and the fact that larger technical investigations are needed in order to find the exact output. Theory on the subject is also simplified in order to give the possibilities to calculate the output, knowing that there are possibilities for deviation between the theoretical found output, and the practical output. The focus in this project, will therefore be on finding the factors essential for the output, but to simplify the calculations to only in count the factors that are easy useable.

- The sale options to the produced biogas, has been delimited to one option. The option selected is selling the biogas as electricity, converted through a gas engine. This option is selected, due to this being the most common method of converting produced biogas into energy. It is found necessary to delimitate the options to only one, in order to compare the plant offers from the manufactures on the same basis. This option is selected knowing that two other options are available, selling the biogas pure or upgrading the biogas to the natural gas grid.

- It is made as a precondition to the business case, that the gas engine converting the biogas in to electricity has access to the national grid. This is selected, knowing that legal issues are related to the grid connection. The legal issues will not be addressed in this thesis, due to the fact that a grid connection is needed in order to calculate the profitability in the symbiosis.

- It is made as a precondition in the symbiosis that all degasified biomass is returned to the organic farmers. This enables the farmers of generating a profit from using the degasified biomass as fertilizer. The degasification of the crop biomass, in the biogas process is expected to increase the fertilizing ability in the biomass, which will make the biomass a valuable fertilizer. The degasified biomass is therefor found to be interesting as a sellable product for the biogas plant. But as stated is it a precondition to the symbiosis, that the fertilizer is returned to the farmers, following that the degasified cannot be sold as a product from the biogas plants.

- The degasified biomass from the biogas plants, offered by the manufactures, can be in different conditions. The fertilizer can hereby be fluid or solid, based on the capabilities of the biogas plant, and the technologies used in the plant. Fluid fertilizer will be easier adaptable by the crops, than the solid fraction, and the fertilizer is therefor used best on different stages in the crops growth process. But the level of adaptability is found to be highly complex determine. Therefor is it accepted for this project that the fertilizer has the same adaptability, knowing that the fractions will have different ability. Also is the selected in order to be able to compare the plant offers within the same conditions.

- Possible cost for seeding the crops for biomass is not included, in the calculation of the cost related to the farmers. This is due to the fact, that it is expected that the biomasses can be found in the farmers current crop rotation, and their therefor is no cost related to seeding of the biomasses.

1.5 STAKEHOLDERS TO THE THESIS

The main object of the thesis is to investigate the symbiosis between organic farmers and biogas Plants, and the synergy towards national policies on the two areas. But in order to clarify the objects of this thesis this section will describe the interests for all stakeholders to the project.

Organic farmers

Their interest is to investigate the profitability in cooperating with biogas Plants, by supplying biogas Plants with biomass, and be recipients of the degasified biomass, hereby using the degasified biomass as fertilizer. The object is to show the possible profitability in the cooperation, and to investigate the important factors in the cooperation there need to be in place, in order for the farmers to be a part of the symbiosis. This will be shown by applying a case study of three farmers wanting to be part of a symbiosis with a biogas plant.

Biogas plant

For the biogas plant the interest is whether a profitable investment is found in the cooperation with the organic farmers. This is due to the fact that a profitable return on the investment in a biogas Plant is needed in order to find investors for the biogas Plants. Another object in the thesis is to find the barriers the biogas plants has to overcome when being developed and build, in order to clarify this area for possible investors. All this are investigated in the case study, which is also used to investigate the organic farmers.

The symbiosis

The object of the symbiosis is to find cooperation between the organic farmers and biogas plant, which works in a way that makes it profitable for both parties. The focus is to investigate the financial and technical difficulties in the cooperation, and find solutions to the difficulties that make the symbiosis interesting for both parties. The focus will be on finding the costs that are related to the symbiosis, and hereby the shared costs between the organic farmers and biogas plant.

National political interest

There are great political interests in both biogas and organic farming, which have been described in the introduction and the problem statement. Therefore, it is an object for this thesis to find the synergy between the national policies and the symbiosis, in order to make development of relations between relevant parties possible. The project should help to highlight the synergy there is between the national political interest for biogas and organic farming, and the symbiosis that can be created between organic farmers and biogas plants.

VFL

The project is defined in cooperation between the key stakeholder, VFL and the researcher. Based on the fact that VFL has an overall project that uses this thesis to conduct investigations and analysis for the answering of their own project, it is found that the objects in the two projects are highly similar. VFL's object with the two projects is to increase the internal knowledge of organic biogas plants, and to analyze the possibilities for development, in order to deliver knowledge to their customers. Another object with the two projects is to increase their knowledge on how to approach and handle development of biogas projects. These objects are found through the solving of the case study about the symbiosis.

Researcher
The object for the researcher in the thesis is to solve the problem statement found in cooperation with VFL, and to do it by delivering a report that can be used by VFLs in the future work in the field, and to pass the Master program MSc. in Technology Based Business Development at Aarhus University.

Plant manufactures
The manufactures of biogas plants will also have an interest in the thesis, due to the possibilities to sell biogas plants in Denmark. Their object will be to find a high degree of profitability in the symbiosis, based on collaboration with a plant manufactured by them. Their interest will be investigated based on the case study, hereby highlighting the profitability in using their product in the symbiosis.

Universities and knowledge centers
The object of the project could be interesting for universities and knowledge centers, hereby providing with investigations and analyses. Their interest in the thesis is to make further research based on the findings and recommendations from the project, hereby navigating them in the right direction.

1.6 METHOD

This section will describe the method and approach that have been selected for this project.

1.6.1 Research paradigm

The sections will find and describe the research paradigm chosen for this thesis. This is done based on the knowledge found through the preliminary study. The paradigm selected will be described and reasoned through the following three sections, answering the three basic questions for determining a paradigm for an inquiry (Guba, The paradigm dialog, 1990). The paradigm selected for this thesis is the post-positivistic paradigm (Guba & Lincoln, Competing paradigms in qualitative research, 1994).

1.6.1.1 Ontology

"What is the nature of the knowable, or what is the nature of the reality?" (Guba, The paradigm dialog, 1990)

On this level the post-positivism is described as seeking objectivism, which is the only truth, knowing that reality is assumed to exist but cannot be fully found through the seeking for objectivism (Guba & Lincoln, Competing paradigms in qualitative research, 1994), due to human interference. This is found to be the right approach for this research, due to the fact that we know there is a truth to the inquiry in this thesis, but that the fully truth cannot be found. But the objectivism in this thesis, leads to the fact that the areas found will be investigated thoroughly in order to get as close as possible to the truth. Knowing this, the approach of critical realism (Guba, The paradigm dialog, 1990) will be used in this research, allowing the researcher to have an approach that will seek to find the truth, knowing that the full objectivity cannot be achieved, due to human interference. The seeking for the truth will be conducted through investigating all possible objects, found in theoretical and empirical studies.

1.6.1.2 Epistemology

"*What is the nature of the relationship between the knower (the inquirer) and the known (or knowable?"* (Guba, The paradigm dialog, 1990)

Having selected post-positivism, and hereby the critical realist approach, it is accepted that modified objectivism will be used, striving to seek objectivism. But hereby also acknowledging, that the human interference will mean that total objectivism cannot be reached (Guba, The paradigm dialog, 1990). This will define how the researcher will approach the research, striving to have objectivism as an ideal. In order to seek this objectivism, as many sources as possible will be investigated, hereby acquiring new knowledge. This is done through a theoretical and empirical study, covering as many angels on the inquiry as possible in the research, which hereby will give a range of angles on the problem statement found through the preliminary analysis.

1.6.1.3 Methodology

"How should the inquirer go about finding out knowledge?" (Guba, The paradigm dialog, 1990)

Based on the answers at the ontological and epistemological level, critical multiplism is selected at the methodological level (Guba, The paradigm dialog, 1990). This choice will mean that the findings from the researcher will be tested and verified, in order to falsify or validate the result found based on the theoretical and empirical study. Testing and verification of the results will help the researcher to strive after objectivism, getting closer to the fully truth by the falsification or validation of the results found. In order to get closer to the fully truth, selecting post-positivism as the overall approach allows both qualitative and quantitative studies to be conducted, getting a more for filling answer to the inquiry. The qualitative studies will mainly be used in order to verify and validate the data collected through quantitative studies.

1.6.2 Research strategy

This section will describe the research strategy selected for solving this project, based on the research paradigm selected and the research question made for the project.

The retroductive research strategy (Blaikie, 2010) has been selected as the strategy for this project. This approach is selected due to the central problem in the retroductive research strategy, being to discover structures and underlying mechanisms that are proposed in order to explain regularities that have been observed. But in order to use this research strategy, parts of the three other research strategies (Deductive, Inductive and Abductive) (Creswell, 2009) will be used in the preliminary study, to observe the regularities that is to be explained in the project. This will help determine what needs to be investigated in the following phases using the retroductive research strategy. The selected strategy will enable the findings from the investigations to be constructed in to, e.g. a model, from where further investigations can be conducted. The overall aim of the retroductive research is to test a hypothetical result over and over again, hereby continuously discovering ass many new angles to the problem as possible. By conducting this continuously throughout the project, the findings will be verified or falsified throughout the process of conducting the project, hereby getting as close to the fully truth as possible, which is the objective in the selected paradigm.

1.6.3 Research methods

The methods that will be used in the project will be described in the following section.

Following the selection of the post-positivistic paradigm, and the retroductive research strategy, a research method of mixed methods are to be used throughout this project. This is selected as the method for this thesis, due to the use of both qualitative and quantitative research. This is in line with the overlaying approaches from the paradigm and research strategy (Guba, The paradigm dialog, 1990), compared to using only qualitative or quantitative research in the project (Creswell, 2009). This mix of methods will enable the verification or falsification of the findings throughout the project, and will help discover new angles to the findings. However, this approach will lead to a never ending investigation on the area. But in order to answer the research questions with in the time limit, the research is finished within the time limit, ending out with a result and recommendations for further work. The approach it therefore selected, in order to be able to investigate as many areas as possible within the time limit of the project. The methods used in the thesis are described in the following sections.

1.6.3.1 In-depth case study and workshop

In order to understand the symbiosis and synergy, and in order to determine what should be investigated in the following phases, in order to be able to answer the research questions, a case study from the overall project is used. The case study will be used to clarify the areas that need to be investigated in order to analyze the symbiosis, and also to find synergy towards the national policy. In order to elaborate the areas that need to be investigated, the researcher will participated in an organic biogas seminar, where the problems the problems and opportunities in organic biogas will be addressed. Participation in this will help extend the level of knowledge within the researcher and help identify further areas that need to be addressed. Also the seminar gives the opportunity to develop relation to people with knowledge of the areas that needs to be addressed when developing a biogas project. These persons will be interviewed in order to further understand a biogas project and the areas that need to be investigated. The use of a case study and a workshop will also help define the areas that need to be verified or falsified in the following phases.

Sjællandcase

The case used in this project is adapted from the overall project. The case is investigating three organic farmers in Sjælland, Denmark, with a shared idea of initiating a biogas project with the goal of acquiring organic fertilizer to their crop production. The case study will investigate the available biomass in the farmer's crop rotation, and the objectives and preconditions the farmers has towards a possible biogas project. The case study will end up with a definition of the tasks VFL should handle in the project.

Workshop

The organic biogas workshop was held by organic Denmark, as a part of the Sustaingas project[5]. The object of the workshop was to have all interested organizations and farmers educate each other and discuss the problems areas found when working with organic biogas. The researchers object by participating was to understand the problem areas when developing a biogas project, in order to investigate them later in the project. Also the participation gave opportunity to make contact with other participants, with the object of getting further understanding of the problem areas, through interviews.

1.6.3.2 Mapping and visualization

Based on the findings from the case study and the workshop, maps and visualizations will be made in order to give a better overview over what needs to be investigated and conducted in the project in order to answer the research question. Maps will be made over the symbiosis and the synergy, in order to understand the interaction within them and the interaction in between. Also there will be made visualization over the approach VFL will use for conducting a biogas project. The approach will be used in order to solve the overall project, and answer the questions regarding the profitability in working with organic biogas

[5] Sustaingas project - http://www.sustaingas.eu

in this project. VFL approach for biogas projects will be found based on the knowledge found in the case study and the workshop, together with the experience from the employees in the bioenergy department at VFL. The result of this method will be verified by experts related to the symbiosis, synergy or VLFs approach towards biogas projects. This is done in order to ensure that the result is right, before investigating the areas further in the following phases.

1.6.3.3 Literature study

A literature study is conducted in the object of finding literature that can help solve the problem areas found within organic biogas projects and to answer the research questions. In order to do this, the knowledge found in the preliminary study together with the mapping and visualization will be used to search after the appropriate literature. The literature study will be divided into two main sections, one concerning the relevant literature for investigating the factors in the symbiosis, the second section concerning the relevant literature for investigating the factors in the synergy. Literature is found based on theory obtained at the MSc. in Technology Based Business Development program at AU Herning, interviews with experts, individual research and internal material from VFL. The individual research is conducted as an exploratory process, based on online search after scientific articles, journals, projects in the same field from companies and universities. The exploratory process used in the literature study is illustrated in figure 5 – *Knowledge levels* and is used in order to obtain and use as much new knowledge as possible in the project. The object of the process is to convert as much knowledge from level two and three to level one, hereby having getting a continuously better knowledge base throughout the literature study. This I also in line with the retroductive research strategy selected for this project.

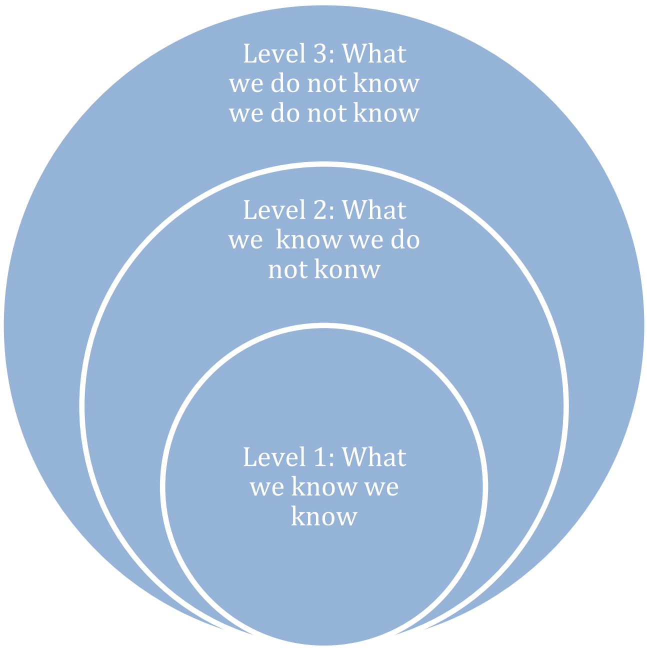


Figure 5 - Knowledge levels (Darsøe, 2011)

1.6.3.4 Economic and technical calculations

Based on the case study and the found knowledge in the literature study, economic and technical calculations on a biogas plant for the case will be conducted. Based on the findings in the case study and the literature study, plant manufactures will be asked to come with an offer on how a plant for the Sjællandcase should be constructed. This will be used in order to calculate technical areas of the biogas project, related to the input of biomass and the output of biogas and degasified biomass (fertilizer). The technical calculations will hereafter be used in order to calculate the profitability in the symbiosis between the organic farmers and a biogas plant in the Sjællandcase. Hereby it will be possible to come with a valid assessment on profitability in an organic biogas project, verifying if the symbiosis can be made profitable for both parties in the symbiosis. The findings from this method will be presented for the commissioning party in the Sjællandcase and related experts, in order to verify the result and the findings from the calculations.

1.6.3.5 Policy analysis

The synergy towards the symbiosis is found through the case study and workshop, and was further investigated through the introduction. Based on the found knowledge from these areas the national political interest towards organic biogas projects will be analyzed, in order to assess the support towards this. Analyzing the policies towards organic biogas plants and the organic farmers, will help determine the synergy towards the symbiosis, and which areas to focus on in order for both parties to develop the organic biogas area further. The analysis will be made through a discussion, highlighting the areas that are found interesting based on the investigations conducted in this project. The found focus areas will be also be verified through interviews with key actors and experts, with in the areas of organic farming and biogas production.

1.6.3.6 Interviews

Through the entire project interviews and conversations is conducted, with a variety of different persons, both by face-to-face and phone interviews. The same strategy as in figure 4 – *Knowledge levels,* will be used in the interviews and conversations, in order to develop as much knowledge as possible through the interviews. In the initiating phases of the projects, unstructured interviews and conversations will be used, in order to gain the needed knowledge from VFL and the problem that is to be solved. Later in the project when knowledge about the company and the problem is acquired, semi-structured interviews will be used. Semi-structured interviews are used due to the multiple answering possibilities from the respondent, which allows the respondent to give more knowledge to the interviewer than when using structured interviews. This especially comes in to use when conducting the case study and participating in the workshop, where the persons interviewed needs to deliver as much knowledge to the researcher as possible. Therefore it is only needed for the researcher to structure the direction of the interviews, and not to structure every question in the interview. Prior to all interviews, the respondents are presented with a list of topics to be answered in the interview, based on an interview guide[6]. Hereby is the direction of the interview determined by the researcher, but the respondents determine the knowledge outcome.

1.6.4 Validity and reliability

A mix of different theories has been selected in the research method for this research. The importance of the validity and reliability cannot be underestimated, hence the study has to be based on trustworthy research, in order to create value to the stakeholders. The trustworthiness from the literature review is found to be good, due to the fact that the theory is collected through scientific articles, based on knowledge generated through unstructured interviews with experts. The use of both methods for the literature review will verify the knowledge generated, in an iterative manner. The empirical data will be collected through the case study, and the participation in the organic biogas workshop. In the empirical data collection, unstructured interviews and conversations will be used, based on the developed interview guide[7]. This will decrease the bias for the human affect, which could be found in the empirical data collection. The internal sources in VFL are expected to

[6] Appendix 2 - Interview guide
[7] Appendix 2 - Interview guide

be highly trustworthy, due to their own interest in this project, and the same is expected from organizations in relation to VFL, e.g. Agrotech. The data collected from plant manufactures is questionable, due to the fact that they are having multiple interests in the project. The main aim from the manufactures is expected to be to sell their products, as good as possible. Therefor are the plants offers from the manufactures, verified through the found literature, and from interviews and conversations with experts. The result of this project is a business case, where all gathered knowledge is used in order to calculate the profitability in the symbiosis, hereby validating the found knowledge. The overall result is considerate as valid, due to the objectivistic approach used throughout the project. The validity and reliability in the research will be reflected upon in the final conclusion to the project.

1.6.5 Method model

This section will show and describe the method model used in this project. Firstly the model will be presented in figure 6 – *The Method Model for the project*, hereafter is each of the phases in the model described in a section underneath.

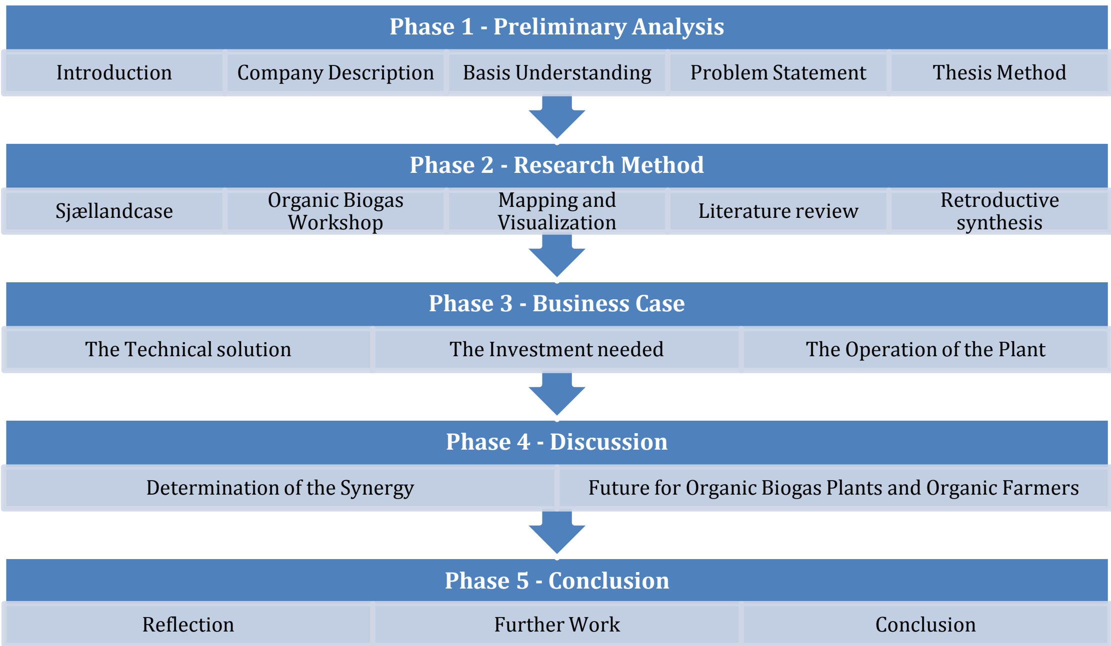


Figure 6 - The Method Model for the project

1.6.5.1 Phase 1 – Preliminary analysis

The first phase of the project is used in order to introduce the problem background the project is based upon. Hereafter is the company conducting the project described, in order to understand the company and the departments that are to solve the problem. Based on the problem background in the introduction, the problem statement is presented, describing the main problem and what needs to be investigated. The problem statement is ending in a research question, which will be the main object for the project to solve. After the problem statement, stakeholders to the project are described in order to understand their objects in the project, and to ensure that the project focuses on solving these. Delimitation to the project is made, to point out the areas where the project is limited due to different factors. Based on the research question and problem statement, a research method for the project is developed, hereby following this method throughout the remaining project.

1.6.5.2 *Phase 2 – Research method*

Empirical and literature study will be conducted in this phase, ending in an analysis and validation of the findings.

1.6.5.2.1 Case study

Due to the lacking knowledge about organic biogas projects and the need for determining important factors to investigate in the project, a case study is selected. The case study is adapted for the overall project, and is used for analyzing, which areas need to be investigated in the symbiosis between organic farmers and biogas plants, and in the synergy towards national policies. The phase will describe the Sjællandcase from the overall project, through meetings and interviews with the three farmers in the case. The case will present the objectives and preconditions to a biogas plant, and determine what VFLs task in the project is. In addition to understand the problems with organic biogas projects further, an organic biogas workshop is attended and the findings here from will be described after the Sjællandcase. Also interviews with experts and farmers from the workshop are described after the case, in order to elaborate the areas that need investigation further. The phase is ending with a sum-up section that highlights the main findings in the case study.

1.6.5.2.2 Mapping and visualization

This phase will be used in order to illustrate the findings from the preliminary study and the case study. The first section in the phase will be used in order to map the findings about the symbiosis and the synergy, in order to understand and structure the following investigations in the fields. After the maps, a short description will made in order to elaborate the maps and the understanding of them. Hereafter will the approach VFL should use for developing a biogas project, be investigated and presented. This will be done based on internal material and interviews with key employees in the bioenergy department. These persons will also be used in a later evaluation of the biogas project approach in the discussion phase.

1.6.5.2.3 Literature review

Literature will be found and presented in this phase, based on the findings in the previous phases, and be structured based on the maps made in the previous phase. The literature study will be divided in to two main sections, which will be divided in to further sub-sections. The main sections will be made according to the literature relevant for the symbiosis and for the synergy. The literature found for the symbiosis will be divided in to two sub-sections, one for the literature relevant for the organic farmer, and the other with literature relevant for the biogas plant. The literature found for the synergy will be divided into three sub-sections, one presenting the literature found about sale of biogas, another presenting the national policies found and the last presenting the international policies that affect the national policies. The phase will be ending in a sum-up section that highlights the findings from the entire literature study.

1.6.5.2.4 Retroductive synthesis

The findings from the prior phases will be analyzed and validated in this section, in order to use the found knowledge in the business case and in the following discussion. The object of the section will be to verify the calculation methods found in order to be able to analyze the plants offers received for the business case in the best manner. This section should also make it possible to calculate the profit that can be generated by the farmers, and the cost that are found to be in the symbiosis.

1.6.5.3 *Phase 3 – Business case*

The business case will be used in order to answer how a biogas plant for the Sjællandcase could be made. The phase will firstly contain a description on the technical solutions found for the plant in the Sjællandcase. Secondly it will contain a description on the investment needed for the plant, based on different scenarios. The technical solutions and investment needed is found from plant manufactures, which have been asked to make an offer on a plant for the case. Having the knowledge of the technical solution and the investment needed for the plant, calculations on the profitability of the plant will be calculated. The calculations will be divided in to three areas, the first calculating the earnings the organic farmer can make on being a supplier to the plant, the second calculating the earnings the biogas plant can make, producing the biogas. The earnings from the two can then be used to determine the economic structure that is needed in the symbiosis, in order to make it profitable for both parties. The phase will end out in a business case that presents the best solution for the Sjællandcase, in order to for fill the objects and preconditions found in the case. The business case will be presented for the commissioning party in the Sjællandcase and to relevant experts in order to verify the results.

1.6.5.4 Phase 4 – Discussion

Based on the found knowledge in the previous phases a discussion will be made assessing the areas found important. The first discussion will concern the possibilities in the symbiosis between organic farmers and biogas plants, based on the literature found, and the business case made over the Sjællandcase. This will also contain an evaluation of the validity of the result in the business case, and the possibilities to relate the result to other organic farmers in the same situation. Following this, a discussion will be made determining the synergy between the symbiosis and national policies regarding biogas and organic farming. This discussion will also highlight the areas that need to handle, in order to give the best possibilities for the symbiosis. The phase will end up in recommendations to the stakeholder for this project, based on the findings in the entire project.

1.6.5.5 Phase 5 – Conclusion

The last phase of the project will be divided into three sections. The first reflecting on the results found in the project, and the possibilities for other results if another method or approach was selected. The second will focus on the further work, that is found to be interesting in relation to the project and the results found. This will include, suggestions on which areas VFL should focus on in their continued work in the field. The last section will contain the conclusion of the project, including answering of the research questions.

2. RESEARCH METHOD

The research method phase will contain five sections. The sections and their purpose in the data collection can be seen in figure 7 – *Steps in the research method*.

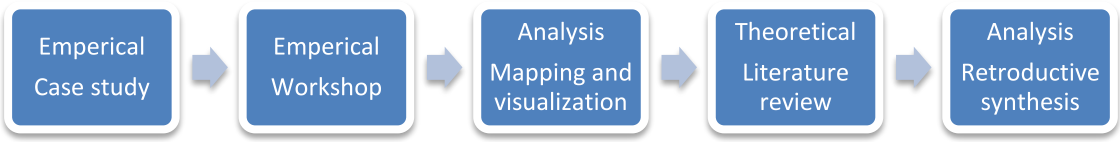
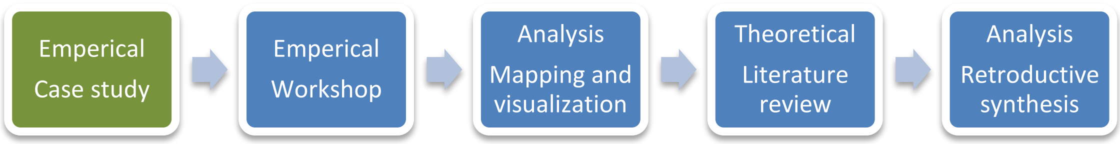


Figure 7 - Steps in the research method

The first section will contain a case study on a symbiosis, which is found based on a specific case with three farmers. The second section will contain a description of findings made from participation in a workshop, and interviews with other participants, this in order to find barriers in the symbiosis and the synergy towards national policies. The third section will contain visualization and mapping of the symbiosis and synergy, based on the findings from the two previous sections. This section will also contain a description of the biogas project development process identified within VFL. The fourth section will contain a literature review, of the literature used in order to investigate the symbiosis between the organic farmers and the biogas plant. The literature study will be conducted based on the knowledge found in the three previous sections. The fifth section will be a retroductive synthesis, in order to validate the findings from the literature.

2.1 CASE STUDY



In order to investigate the symbiosis between the organic farmers and biogas plant, and the synergy to the national policy interest, a case study is used. The case study selected for this project is from VFL project, and is based on three organic farmers in Sjælland, in East Denmark. The reason for using this case in the project is that all three farmers are crop farmers with no animal production, which is leading them to dependency of animal fertilizer from conventional farmers in the local community. Therefore, they are in need of a way of getting access to more fertilizer that is organic. The Sjællandcase will be used throughout this project in order to investigate the symbiosis and synergy, and calculate the profitability in the symbiosis. The case study will be used to develop maps over the symbiosis and synergy, and an approach on how VFL will develop a biogas project.

2.1.1 Sjællandcase

The three organic farms are all located in the Vest of Sjælland, which is illustrated in figure 8 – *Location of the farmers in the Sjællandcase*. The reason for using these farmers and location as a case in this project is that there is a low amount of animal production in this area, especially organic animal production. Therefore, the three farmers are depending on the animal fertilizer they can acquire from the few conventional animal productions there are nearby located. Another reason for selecting this as a case is the fact that all three farmers have a similar production, and that the production they have, is found to be normal for organic farmers with only crop production[8]. Together they are producing organic crops

[8] Conversation with Peter Mejnertsen at VFL – Appendix 4 – Interviews/conversations

on 2.323 ha. The case is found and described based on several meetings with the three farmers[9].

Figure 8 - Location of the farmers in the Sjællandcase

2.1.1.1 *The Organic farmers*

In the following sections, each of the three farmers will be presented, hereby presenting their crop rotation and the biomasses they can offer to a biogas plant. The farmers have evaluated their crops rotation, and have stated the amount that could be available as biomass for a biogas plant. This is done with the precondition that the three farmers can maintain their current setup. It is expected that only 1/3 of the total amount of straw is available as biomass, due to the use of straw as structure material for the soil and the costs of producing high quality straw. Also, an amount of the area with spring cereal will be seeded with additional clover grass, which is equal to the amount of annual clover grass, hereby being harvested as straw + clover grass in late fall, and clover grass in the following year. Due to the fact that fertilizer also can be used as biomass in a biogas plant, the amount of fertilizer available for each of the farmers is also described, this also in order to understand the amount of fertilizer available for the farmers. Following the presentation of the three farmers, their joint objects for the biogas project will be described together with the preconditions to the project.

2.1.1.1.1 Christian Jørgensen

Christian is running two farms, his home farm at Arnakke with 275 ha and Svenstrup Gods with 548 ha. The two farms is located 57 km apart, with Svenstrup Gods is located some way from Niels and Peters farms. Due to the bad location of Svenstrup Gods and the fact that it is expected to be able of find an equal amount of biomass nearby Arnakke, the total amount of land and biomass is calculated as being located in Arnakke. The distance to Niels is 15 km, and the distance to Peter is 27 km.

Crop	Ha	Percent	Biomass	Ton
Spring cereals	309	37,5	Straw	239
Winter cereals	154	18,7	Straw	118
Winter rape	120	14,6	Straw	93
Grass seed	100	12,2	Seed grass straw	400
			Regrown seed grass silage	100
Red clover grass for seed	60	7,3	Clover grass silage	361
			Straw + Clover grass silage	420
White clover grass for seed	60	7,3	Clover grass silage	361
			Straw + Clover grass silage	420

[9] Appendix 3 – Interview med commissioning party

Carrots	20	2,4	Carrots + tops	300
Total	**823**	**100**	**-**	**2.812**

Table 2 - Annual crop rotation Christian Jørgensen

The average fertilizer use is at 70 kg N per ha, which is only from conventional animal manure. No organic fertilizer is used in the current crop rotation.

Fertilizer	Ton	Kg N per ton
Conventional pig slurry	10.000	4
Conventional cattle slurry	400	3,5
Conventional cattle deep straw	100	8,5
Total	**10.500**	**-**

Table 3 - Annual fertilizer use Christian Jørgensen

2.1.1.1.2 Niels Mejnertsen

Niels is running one farm located near Viskinge, where from he is also running a grain mill, producing organic flour and other products based on organic grains[10]. He is importing organic grain from other organic farmers on Sjælland, and smaller amounts from farms located in Fyn and Jylland. This is resulting in an amount of waste grains from the mill, which can be used as a biomass. He is acquiring an amount of organic cattle manure from an organic cattle farm called Mineslund[11], which is located nearby. Niels is located 15 km from Christian and 38 km from Peter.

Crop	Ha	Percent	Biomass	Ton
Spring cereals	375	46,9	Straw	286
			Separated grains	200
Winter rape	120	15	Straw	92
Winter cereals	95	11,9	Straw	72
White clover for seed	80	10	Clover grass silage	481
			Straw + Clover grass silage	280
Seed grass	60	7,5	Seed grass straw	240
			Regrown seed grass silage	60
White clover for green manure	40	5	Clover grass silage	241
			Straw + Clover grass silage	140
Permanent grass	30	3,7	Grass silage	90
Total	**800**	**100**	**-**	**2.182**

Table 4 - Annual crop rotation Niels Mejnertsen

The average fertilizer use is at 70 kg N per ha, which mainly is coming from conventional animal manure, with a smaller amount coming from organic animal manure.

Fertilizer	Ton	Kg N per ton
Conventional pig slurry	12.000	4
Organic cattle deep straw	2.000	8,5
Total	**14.000**	**-**

Table 5 - Annual fertilizer use Niels Mejnertsen

2.1.1.1.3 Peter Mejnertsen

Peter is located near Tølløse, where all his land is located. He is acquiring organic fertilizer from an organic animal farmer nearby. He is using yellow mustard as a catch crop, which is reducing the area with straw + clover to half of the 60 ha. Peter is located 27 km from Christian and 38 km from Niels.

[10] http://www.mejnerts.dk/da/mejnerts/molle.html
[11] http://www.mineslund.dk/

Crop	Ha	Percent	Biomass	Ton
Spring cereals	280	38,3	Straw	247
Seed grass	160	21,92	Seed grass straw	640
			Regrown seed grass silage	60
Permanent grass	80	10,6	Grass silage	320
Winter cereals	60	8,22	Straw	53
Legume crops	60	8,22	-	-
Clover grass for green manure	60	8,22	Clover grass silage	541
			Straw + Clover grass silage	210
Yellow mustard as catch crop	30	4,11	Yellow mustard silage	150
Total	**730**	**100**	**-**	**2.221**

Table 6 - Annual crop rotation Peter Mejnertsen

The average fertilizer use is at 90 kg N per ha, which mainly is coming from conventional animal manure, with a smaller amount coming from organic animal manure.

Fertilizer	Ton	Kg N per ton
Conventional pig slurry	10.000	4
Conventional cattle deep straw	3.000	8,5
Organic cattle slutty	2.000	3,5
Organic cattle manure	1000	8,5
Conventional pig deep straw	600	11
Organic cattle deep straw	600	8,5
Conventional poultry manure	500	21
Total	**17.7000**	**-**

Table 7 - Annual fertilizer use Peter Mejnertsen

2.1.1.2 Biomasses in the biogas project

The following tables show the amount of biomass available in the case. For each biomass the amount of fresh matter (FM) and the amount of dry matter (DM) is found.

Biomass	DM %	DM ton	FM ton
Clover grass silage	37,9	752	1.985
Straw + clover grass silage	42,3	621	1.470
Seed grass straw	85,0	1.088	1.280
Straw	85,0	1.020	1.200
Permanent grass silage	37,1	152	410
Carrots + tops	17,6	52	300
Regrown seed grass silage	34,7	76	220
Separated grains	85,0	170	200
Yellow mustard silage	15,5	23	150
Total		**3.957**	**7.215**

Table 8 – Organic biomasses in the biogas project

Biomass	DM %	DM ton	FM ton
Cattle deep straw	27,5	715	2.600
Cattle slurry	8,0	160	2.000
Cattle manure	27,5	275	1.000
Total		**1.150**	**5.600**

Table 9 - Organic animal fertilizer for the biogas project

Biomass	DM %	DM ton	FM ton
Pig slurry	4,0	1.280	32.000
Cattle deep straw	27,5	852	3.100
Pig deep straw	25,3	165	600
Poultry manure	45,0	225	500
Cattle manure	8,0	32	400
Total		**2.555**	**36.600**

Table 10 - Conventional animal fertilizer in the biogas project

2.1.1.3 Objectives for the biogas project

The biogas project is based on objectives from the three organic farmers that are the commissioning party to the biogas project. This section will describe the objectives they have for the project, hereby giving an understanding into why they want an organic biogas plant to be constructed.

2.1.1.3.1 Access to more organic fertilizer

The commissioning party wants access to a larger amount of organic fertilizer, and organic fertilizer that is more efficient. Cooperation with a biogas plant should help get access to a larger amount of fertilizer, which will help the farmers to a better supplier security to the fertilizer they are depending on. This shall be done by the farmers supplying a biogas plant with biomass, and receiving the degasified biomass in return, which hereby become a fertilizer. At the moment, the farmers are highly dependent on the amount of conventional animal fertilizer they can acquire from the few animal farms nearby. The dependency of conventional animal fertilizer is limiting the development possibilities for the three farmers. Access to a larger amount of fertilizer will give them great development possibilities, e.g. expanding the crop area, getting higher yield, higher quality in the yield or cultivation of high demanding crops on the farmland. The object is not only to give access to a larger amount of fertilizer, but also provide the farmers with fertilizer at a price where it is profitable for them to use it in their crop rotation.

2.1.1.3.2 Recirculation of the residue products

Most of the biomass in the case is residue products from the crop rotation, or related processes to the crop rotation. These residue products are currently spread or plowed into the farmland and hereby used as fertilizer, but the fertilizing ability of the waste products are found to be low. The fertilizing ability is found to be low due to the poor degradability, and leaching of the nutrient content from the residue products. By treating the residue products in a biogas plant, the nutrient content should become much more adaptable to the plants, and therefore the leaching of nutrients should be at a minimum. Cooperating with a biogas plant also gives the opportunity to recycle organic residue products from the production of flower and carrots. The ability to recycle the residue from the productions can be used as a marketing initiative, promoting the farms and their products as sustainable, due to the focus on recycling residue products.

2.1.1.3.3 Crops for biomass found in the existing crop rotation

The object is that the crops and residue products for a biogas plant shall be found in the farmers existing crop rotation. The primarily object with a cooperation with a biogas plant is to get fertilizer, not to get generated income by selling biomass to the biogas plant. Therefore, the crops for biomasses shall not compete for farmland with the current crops, they shall be a part of the rotation, but not steal farmland from the profit generating crops. If the crops for biomass steal farmland from the current crops, the biomass should generate a profit that is equal or higher than what is generated from the current crop. An alternative is to cultivate the crops for biomass in areas with weed problems, where the profit generated with a current crop would be low. But the overall object is that the biomasses for a biogas plant can be found in the current crop rotation.

2.1.1.3.4 The commissioning party only wants to be suppliers

The object for the commissioning party is not to own and/or run the biogas plant, but to find a partner that is willing to invest and run the plant. Hereby is the wish from the commissioning party only to be supplier of biomass for the plant. Therefore is an object that the investment in the biogas plant will yields a return that is so high that it is possible to find a financial partner to invest in the biogas plant. The commissioning party expects that the yield's return of investment should be at minimum 10 percent, in order to make it interesting for a financial partner.

2.1.1.4 Preconditions for the biogas project

Based on the objectives for the biogas project, preconditions to the project are now described. The preconditions are based on the location of the three farmers and the biomass they have available for a biogas plant.

2.1.1.4.1 Organic biomass

In order for the fertilizer to be characterized as organic fertilizer, only organic biomasses are allowed to be used in the biogas plant. The aim is to get fertilizer that is characterized as 100 percent organic. Therefore, conventional biomasses cannot be allowed, unless they can be accepted as organic fertilizer by the governmental institutions. However, due to the fact that there can be technical difficulties with a biogas plant only using the organic biomasses, some conventional biomass is allowed in the plant, if necessary. The allowed amount of conventional fertilizer in the plant is described as following: *"The input conventional N amount must not exceed 25 percent of the total N input"*[12]. Even though it has been allowed to use a degree of conventional fertilizer to overcome possible technical difficulties, the aim for the project is still to produce fertilizer that is characterized 100 percent organic.

2.1.1.4.2 Location of the plant

There are several preconditions to the location of the biogas plant that needs to be taken into consideration in the project. The location of the plant needs to be optimized according to the transportation of the biomasses and the degasified biomass, in order for the profitability in the project to be as optimal as possible. A factor that also will have influence on the location of the plant is the available sales options for the energy produced at the plant. Due to the fact that a gas engine will be used to convert the produced gas into electricity, a large percentage of the gas will be converted into heat, which can be a sales item if the biogas plant is located in an area where the heat can be sold. If the heat cannot be sold, it is a waste product in the process of generating heat, and the possible earnings will therefore be lower. The available sales options to the heat are therefore an important factor in the task of determining the right location.

2.1.1.4.3 Profitability for investors

As stated in the objectives for the project, the project needs to be so profitable that it is interesting for investors to build and run the plant. Therefore, it is a precondition to the project that the annual return of investment in the biogas plant is at a minimum of 10 percent. It is expected that a result at 10 percent or higher, would be enough in order to be capable of attracting investors to the biogas plant.

[12] Appendix 1 – Project description VFL

2.1.1.4.4 Profitability for the farmers

In order to make the symbiosis interesting for the farmers, it is a precondition that there is profitability for them acting as suppliers of biomass and recipients of the degasified biomass in the symbiosis. The profitability in being supplier and recipient to the biogas plant is determined by the extra earnings the farmers can generate from fertilizing their crops with the degasified biomass. Due to the options that become possible with the larger amount of fertilizer, it is difficult to determine a certain grade off profitability that is acceptable for the farmers, because each farmer will have a unique plan on how to use the possibilities made available. But in order to determine the profitability for the farmers, the profitability will be found based on the three farmer's current crop rotation, and the extra yield that will be generated. The profitability found for the three farmers can be used in order to attract more suppliers into the symbiosis, hereby making a larger economic scale in the project.

2.1.1.4.5 Legal commitment to ensure security of supply

Due to the fact that the commissioning party only wants to be suppliers in the symbiosis with a biogas plant, and the fact that the biogas plant and the farmers will become dependent on each other, legal bindings are necessary. The farmers will become highly depended on the amount of fertilizer they receive from the biogas plant, while the biogas plant becomes depended on the biomass received from the farmers. Due to this dependency, a binding legal commitment is found to be a precondition to the biogas project. The binding commitment should prevent the biogas plant from applying other biomasses to the plant, undermining the object of supplying the farmers with fertilizer that are characterized 100 percent organic. The binding commitment also ensures the supply of biomasses to the biogas plant, ensuring that the farmers incorporate the biomasses in their crop rotation. The binding commitment should ensure that both parties in the symbiosis will have a security of supply.

2.1.1.4.6 Partner to handle the biomasses

The biomasses available at the farmers are mostly harvested at a time of the year, where the farmers are occupied in their main business, their existing crop rotation. Therefore, they have made it a precondition that the harvest and handling of the biomasses is conducted by the biogas plant, or by a partner to the project.

2.1.1.5 VFLs tasks in the project

Based on the objectives and the preconditions to the biogas project, it has been agreed, which tasks VFL should handle in the development of the project. The summarizing of the findings in this section will therefor state the tasks, and will therefore also be a conclusion to this step of the research method.

Goal: Business case over the project, containing technical solutions to the plant, investment plan and operational calculations.

Determining location for the plant

- Optimal transport distance between farmers and biogas plant
- Acceptance of the plant location in the local community

Determining the economic factors in the symbiosis

- Transportation of the biomasses and degasified biomass
- Harvest and handling of the biomasses
- Earnings from the gas production and extra yield from the crop production
- Payment of the biomass and degasified biomass

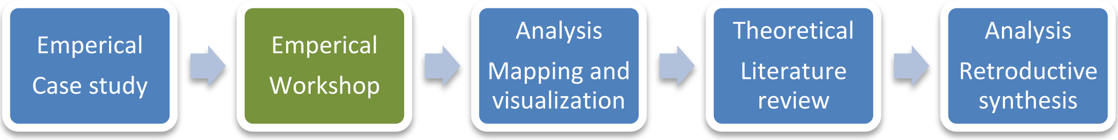
Determining the profitability for the farmers and the biogas plant

- Return on investment for the biogas plant
- Profitability being supplier and recipient for the organic farmers

Determining legal issues that need to be handled

- Binding commitment in the symbiosis
- Required approvals to the biogas plant
- Obstacles that could become legal issues if not addressed

2.2 ORGANIC BIOGAS WORKSHOP



In order to further understand the factors that are important when developing a biogas project, the researcher has participated in an organic biogas seminar, held by Sustaingas[13]. The object of the seminar was to expand the knowledge about organic farming and the problems the organic biogas is facing. In extension of the seminar, the researcher has interviewed organic farmers that were participating, due to their knowledge about the factors in developing a biogas project. Knowledge found through the participation in the seminar and the following interviews will be used to find the areas that need to be investigated in the literature review.

The workshop was participated [14] by a range of different interest organizations, governmental organizations and organic farmers, that all have the object of increasing the amount of organic farming and biogas. Throughout the workshop, the participants were educated in a range of areas within organic farming and biogas, and discussions were made based on the problems there were found by the participants. This section is a description of the findings from the workshop, and is based on transcripts from the workshop[15] and interviews with the organic farmers[16].

The focus is on the barriers that are found between organic crop farming and organic biogas production, and the synergy that can be made toward national political interests. The reason for focusing on organic crop farming, is due to the fact that it during the workshop became clear that organic farmers, with and without larger animal production, have different incentives to why biogas is interesting. The crop farmers are interested in the fertilizer that becomes available through the processing of biomasses, while the farmers with animal production are interested in using the biomasses available to produce energy. The farmers with animal production have the fertilizer needed for their crop production, while the farmers without animal production are in need of more fertilizer for their crop production. The purpose of this project is to get more fertilizer available for the organic crops production. Therefore, it will be the focus point at the workshop.

[13] Organic biogas workshop – Held by Økologisk Landsforening and Sustaingas - http://www.okologi.dk/kalender/biogas-workshop-13032014.aspx
[14] Appendix 5 – Participants in the organic biogas workshop
[15] Appendix 6 – Transcript from the organic biogas workshop
[16] Appendix 7 – Interviews with organic farmers

2.2.1 Areas of interest

The main findings in the workshop are described in the following sections.

2.2.1.1 Technical aspects

The biomasses available from the organic farmers are resulting in a range of difficulties for the biogas plants. The handling and processing of the biomasses in a way that makes it optimal for the process of producing biogas is a difficult task to overcome, especially due to the limited amount of earnings there can be made on the biomasses. Therefore, it is a complex technical task to find a way of handling and processing the biomasses, in a way that makes it profitable for the biogas plant to receive the masses. Therefore, it is found important that the biomasses are handled and processed from the farmers in a way that makes it easy and profitable for the biogas plant to process. But it is also a condition that the handling and processing by the farmers are at a level that makes it profitable for them to be the supplier for a biogas plant. Another technical aspect that comes into account is the amount of biomass the plants should handle, and hereby also the amount of gas that are produced. A technical aspect that is important for the farmers is the biogas plants' handling and processing of the nutrients in the biomass, and hereby also the degasified biomass. Processing the biomasses in a biogas plant is expected to give better fertilizer ability, but there is low focus on the fertilizing ability in the degasified biomass in many of the current biogas plants. Therefore, it is found to be an important technical aspect, to keep as much as possible of the nutrients in the biomass, while producing an amount biogas that makes it profitable. An aspect that is related to the technical aspect is the aspect of using highly skilled employees to operate the biogas plants. It is found to be important to have employees operate the planed that are educated in the field, in order to use the technology right and generate optimal revenue. **Key words: Biomasses, Processing, Handling, Profitability, Skilled employees**.

2.2.1.2 Economic aspects

This is often seen as the most important aspect in biogas plants, due to the impact on almost every other aspect necessary in the process. As described in the technical section, there is a high level of correlation between the technical aspects and the economic aspects of biogas production. In order to get the technical solutions to be feasible to use, there need to be an economic aspect in the biomass and plant. An aspect that is rated highly when defining the economy in biogas production is the possibilities there is for selling the produced biogas. In most current biogas plant, the biogas is converted into electricity and heat by a gas generator, hereby are the selling options related to sale of the electricity to the grid and sale of the heat to customers nearby. A problem related to this is that many of the biogas plants are built far away from areas where it is possible to sell the heat, hereby making electricity the only economical source of earning to the biogas plant. An aspect related to this is the plant's size, which is highly influent on the economic aspects in a biogas plant. A larger plant gives other possibilities economically, but is also dependent on the amount of biomass possible to acquire. An aspect that is influencing highly on the economy in a biogas plant size is the transportation of biomass and degasified biomass. Transporting the biomasses over to long a distance, will have a massive impact on the biogas plant economy. Therefore, it is of great importance to find the optimal location for the biogas plant related to the transportation. The biogas plants are an investment, so there need to be a return on the investment, which should be seen in the profit from both the farmer and the biogas plant. A biogas plant is a large investment so it is not found to be valuable for the farmers to invest in a plant themselves, if the plant is of a commercial size. Therefore, it is seen as a crucial economic aspect, that a biogas plant gives a large enough return on investment, that it is possible to attract financial partners to the biogas plant. **Key words: Technical solution, Sales options, Transportation, Location, Plant scale, Investment.**

2.2.1.3 Political aspects

The political aspects in a biogas plant are found in many areas and in many ways. The political aspects in a biogas plant are what make many of the preconditions and limitations to a biogas plant. There are found many limitations, e.g. the fact that organic household waste can be used in a biogas plant, but that the degasified biomass from the production cannot be rated as organic fertilizer, but is rated as conventional. The aspect found most important is the bureaucratic system, which the farmers and partners have to handle in order to build a biogas plant. The system is found to be highly difficult especially due to the fact that the farmers and partners often have a low level or no experience with the system. There are appointed a biogas taskforce by the government in order to promote biogas plants, but they are unaware of the many difficulties the farmers and partners are facing. The perception is that when a new biogas plant project is initiated, they start at step one instead of being helped through the system by the taskforce. However, there are not only political aspects that make limitations and preconditions, there are also aspects that makes possibilities and framework for biogas production. The support towards biogas production and support toward purchase of the energy produced from renewable energy is what makes the basis of biogas production. Another aspect is the support of organic farming and the use of residues as biomass in biogas plants. This is what makes the framework for the farmers to be supplier of biomass. The fact that there is a biogas taskforce is also an indicator that the government wants to develop the renewable energy sector in the direction of more biogas production. There are found to be many possibilities in the fact that this is a focus area by the government, e.g. by upgrading biogas to natural gas that can be used in the heavy transportation industry, where there is found to be a need for a renewable solution. Therefore, there are found many possibilities in the political aspects, but there are also a common understanding of the difficulties there is in finding and influencing the right political actors in order to change the possibilities into basic conditions for the organic biogas industry. An area where there is a great misunderstanding between the political actors and the biogas industry is the environmental impact of using biogas plants in the production of organic crop production. There is a great need from the organic farmers on showing the political actors that the use of a biogas plant, will lower the environmental impact from the farmers. The common perception in the industry is that this argument would help move the political actors in a better direction. **Key words: Bureaucratic system, Biogas Taskforce, Political actors, Environmental impact.**

2.2.1.4 Legal issues

The legal issues can be related to the bureaucratic system found in the political aspects, due to the fact that the legislation about biogas plants and organic farming have to fulfill are made and maintained by the government. Many of the legislations are found to be barriers for the development of biogas projects, due to the process time and the risk in the outcome of the decisions, because these can be go/kill for the project. But not only are the legislations towards biogas plants and organic farming found important, but also the development of legal obligations internal in the symbiosis between them are found important. As found in the case study are the farmers in need of a financial partner in order to be able to finance biogas plants, which means that legal bindings are needed. The legal bindings should help arrange the organization and the cooperation between the organic farmers and the biogas plant, and help avoid any problems in between them, that could destroy the profitability in the cooperation. The legal biding should define the cooperation, which is found necessary due to the dependencies there are being developed between the two parties. **Key words: Legislation, legal bindings.**

2.3 CONCLUSION EMPIRICAL FINDINGS

The main findings in the case study and workshop will be summarized in this section. The summary will shortly describe the findings that are most important related to the project. The summary will be used in order to show the areas the project will focus on in the following work. The summary will also be used in the generation of a map over the symbiosis and the synergy in the following section.

The Symbiosis			
Actor	**Factors**	**Area**	**Description**
The organic farmers	Crop rotation and the relation to gas and fertilizer potential	Biomass in the crop rotation	The biomasses produced from the farmers should be a part of their crop rotation, If not they need to generate a profit equal or higher that the current crop
		Gas potential in the biomasses	One of the main factors for selecting a crop or its residues as a biomass for biogas production
		Fertilizer potential in the degasified biomass	Another main factor for selecting a crop or its residues as a biomass for biogas production
	Degasified biomass as fertilizer will determine the possible earnings for the farmers	Fertilizing ability in the biomass	The biomass should have an ability to fertilize, which is determined by the biomass being degasified
		Crops ability to use the fertilizer given	The crops ability to absorb the nutrients given through the fertilizer
		Extra yield in the crop rotation	Using the degasified biomass as a fertilizer, should give a higher yield than without the use of this as fertilizer
The biogas plant	The biomass for the biogas plant will determine the biogas plant needed	Technical difficulties with the biomass	The biomass selected for the biogas plant could lead to a range of difficulties
		Limitations in the process	The selected biomass could lead to limitations, due to the content of substances in the biomass
	The biomass and the technical solutions used will determine the output	Output of gas	The selected plant and hereby the technical solution will determine the gas that are extracted from the biomass
		Output of fertilizer	During the process of producing biogas and handling the degasified biomass, the fertilizing ability is expected to improve
The symbiosis	Determination of the location of the plant	Transportation and handling of the biomasses	The transportation of the biomasses and the degasified biomass will have a determining factor on the location selection
		Sales options	Options for selling the produced energy

		for the energy produced	will have a determining factor for where the biogas plant can be located
		Local acceptance	In order to locate a biogas plant and get the needed permissions, local acceptance is needed
		Handling and storage of the masses	The masses need to be handled and storage at a location
	Legal issues	Approval of the location	Before initiating the build of the plant a legal approval of the location is needed
		Environmental approval	Before initiating the build of the plant environmental approvals of the location and plant is needed
		Legal bindings in the symbiosis	Due to the dependence on the other partner in the symbiosis a legal bindings are needed
	Distribution key over the economy in the symbiosis	The biomass	There is a need of determining the pay of the biomass in the symbiosis
		The Degasified biomass	There is a need of determining the pay of the degasified biomass in the symbiosis
		Handling and transportation	The handling and transportation of the masses needs a distribution key, making the symbiosis profitable for both parties

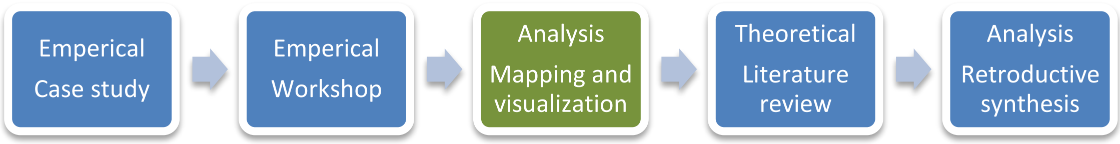
The Synergy

Actor	Factors	Area	Description
National political interest	Promotion and support of biogas	Agreements	National agreements concerning the promotion and use of biogas
		Support	National agreements concerning the support of producers and user of biogas
	Promotion and support of organic farming	Agreements	National agreements concerning the promotion of organic farming, and the production of biomass for biogas production
		Support	National support concerning the promotion of organic farming, and the production of biomass for biogas production
Internatio nal political interest	The influence on the national political interests	Energy agreements	International agreements with an influence on the national politic toward biogas and organic farming
		Agricultural agreements	International agreements with an influence on the national politic toward biogas and organic farming
		Support schemes	International support schemes towards biogas and organic farming, in order to support the symbiosis

2.3.1 Interim conclusion

The investigation in the case study and participation in the workshop, have identified the areas of importance for the researcher. Areas that are needed to be investigated in the symbiosis have been identified, and will make basis for the investigations in the literature review. The findings will help structure the business case, and has identified the framework that will be the basis for the business case. Also has it been determined which results are desired from the business case in order to make the symbiosis interesting for the organic farmers. The investigations in the two sections have also helped identify barriers towards the synergy with national political interest. The found barriers will be used in order to discuss the possibilities for a synergy in the later discussion, where the possibilities will be analyzed. The findings from these two phases will now be mapped in the following section.

2.4 MAPPING AND VISUALIZATION



This section will map and visualize the findings from the previous investigations in this thesis. The section will contain maps over the symbiosis between organic farmers and biogas plants, and the synergy between national political interest and the symbiosis. The last section in this section will visualize and describe the approach VFL will have to developing a biogas project.

2.4.1 The symbiosis and synergy

The knowledge found in the previous phases is used to develop the maps over the symbiosis and the synergy. After each of the maps, a short description will elaborate the maps, in order to ensure the understanding of the maps.

2.4.1.1 The Symbiosis

Based on the knowledge found in the two previous phases a model over the symbiosis is created, mapping the cooperation between the two parties in the symbiosis. This section will shortly describe the symbiosis in relation to the map in figure 9 – *Map over the symbiosis*.

The organic farmers

The input to the symbiosis from the farmers is the biomass that is produced in their crop rotation. The selection of biomass output from the farmers is related to the gas and fertilizing potential in the biomass. The gas potential is the important factor for the biogas plant, where the fertilizing potential is important, due to the returned input of degasified biomass. The outcome of participating in the symbiosis should be extra yield in the crop rotation, and hereby a better profit.

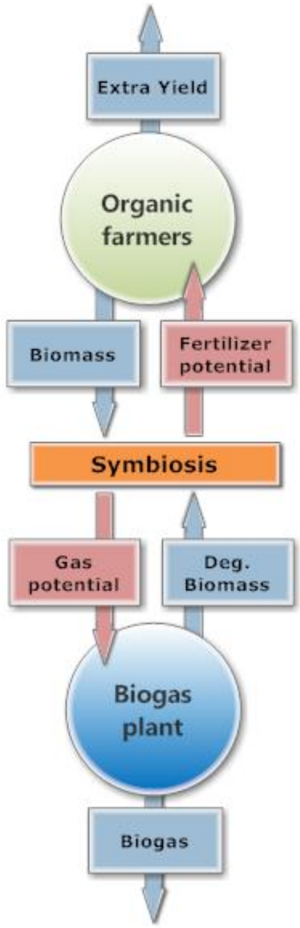


Figure 9 - Map over the symbiosis

The biogas plant

The input to the symbiosis from the biogas plant is the degasified biomass, which has been received as a range of different biomasses and has been degasified in the plant in order to extract biogas. The biomasses interesting for the biogas plant is biomasses with a high gas potential, but also with handling and processing abilities, that makes them profitable to process. The biomasses received, will define the technology that should be used in order to process the masses in an economical profitable way. The outcome of participating in the symbiosis should be an income from the produced biogas, which is high enough to make an investment profitable.

The symbiosis

In order to make the symbiosis function the exchange of masses and the handling of these, need to be arranged after a suiting distribution key. These factors will also influence the location of the plant, and create a need of legal bindings in the cooperation. The symbiosis' goal is to arrange the cooperation in a way that makes it profitable for both parties to be participating.

2.4.2 The Synergy

A map over the synergy is created based on the knowledge found in the previous phases. The map can be seen in figure 10 – *Map over the synergy*, following will a short description elaborate the map.

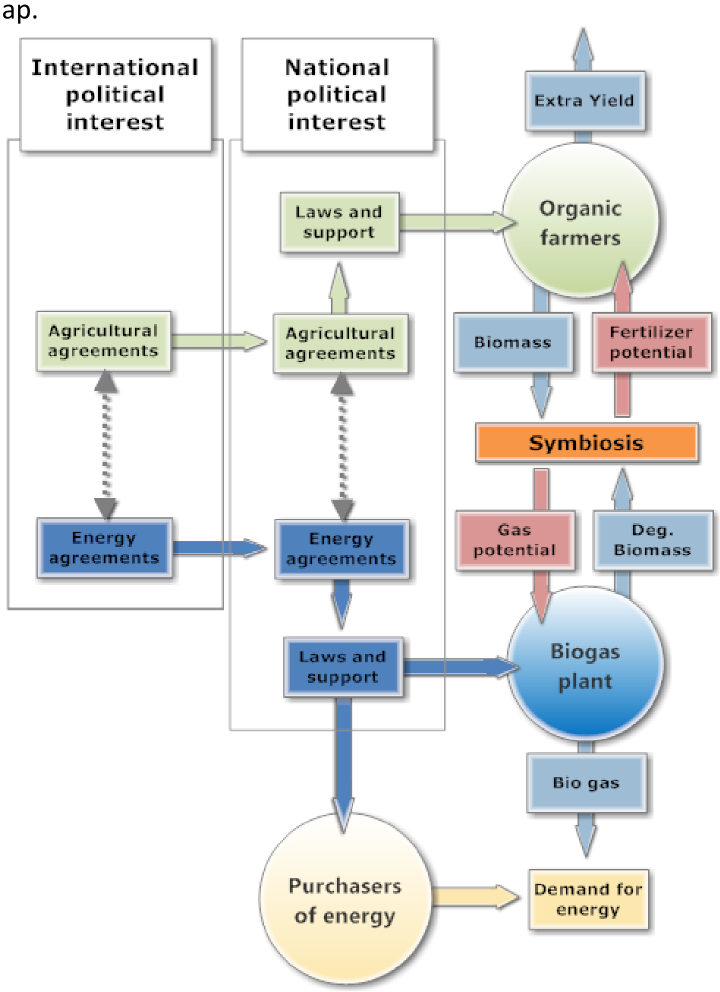


Figure 10 - Map over the synergy

Purchasers of energy
The purchasers of energy produced, are for the electricity the grid, and for the heat is it the local residents. Therefore, it is highly important for the symbiosis that there is an interest in buying energy produced from biogas, and a synergy towards this area is therefore seen as an important factor for the symbiosis to achieve local acceptance.

National political interest
As described in the introduction, there is a high level of national political interest towards biogas and organic farming. Therefore, it is interesting to analyze the interest from the synergy towards the symbiosis between organic farmers and biogas plants. In addition, it is found that there are national political goals, stating that as much energy as possible should be produced from renewable energy. This goal will affect and support the purchasers of energy in buying energy produced from renewable energy, and will therefore have an impact on the synergy towards this area. A link between the policies on organic farming and energy production is also found, which is of great interest for the symbiosis to investigate and create synergy towards, using the relation between the two areas to create synergy.

International political interest
As for the national political interest, the international political interest was described in the introduction, identifying that there is an international interest in organic farming and biogas production. It is interesting to analyze the international interest further in order to identify how this is affecting the national political interest, and hereby how the symbiosis can create synergy, not only towards the national interest, but also towards the international interest.

2.4.3 VFLs approach to biogas projects

In order to understand how a biogas project will be developed by VFL, the approach on how to develop a biogas project has been found. VFL do not have any experience of conducting a full development of a biogas project, but has been used as consultants on parts of biogas projects. It has therefor been investigated, which approach VFL would have to an entire biogas project. This will help conduct the tasks stated in the case study. Conducting the case study based on the found approach will give VFL an insight on whether this is a right approach to develop biogas project by. The approach is developed in cooperation with key employees in the bioenergy department[17], and knowledge found by investigating similar biogas projects. The knowledge found hereby has then been used by the researcher in order to develop the approach. The steps, and tasks identified on each step, have been validated to the key employees, in order to ensure that the approach could function in reality. The approach will in the project be used for developing the biogas project stated in the Sjællandcase. Using the approach to develop the biogas project in the Sjællandcase, will give the researcher the possibility to evaluate the approach in the end of the project, hereby validating the approach for further use. The approach is visualized in figure 11 – *VFLs approach to biogas project*. Following the figure, there is a short description of each step. In appendix 8 – VFLs approach to biogas projects a fully description of each step and the tasks on each step can be found.

[17] Conversation with Erik Fog and Niels Østergaard at VFL – Appendix 4 – Interviews/conversations

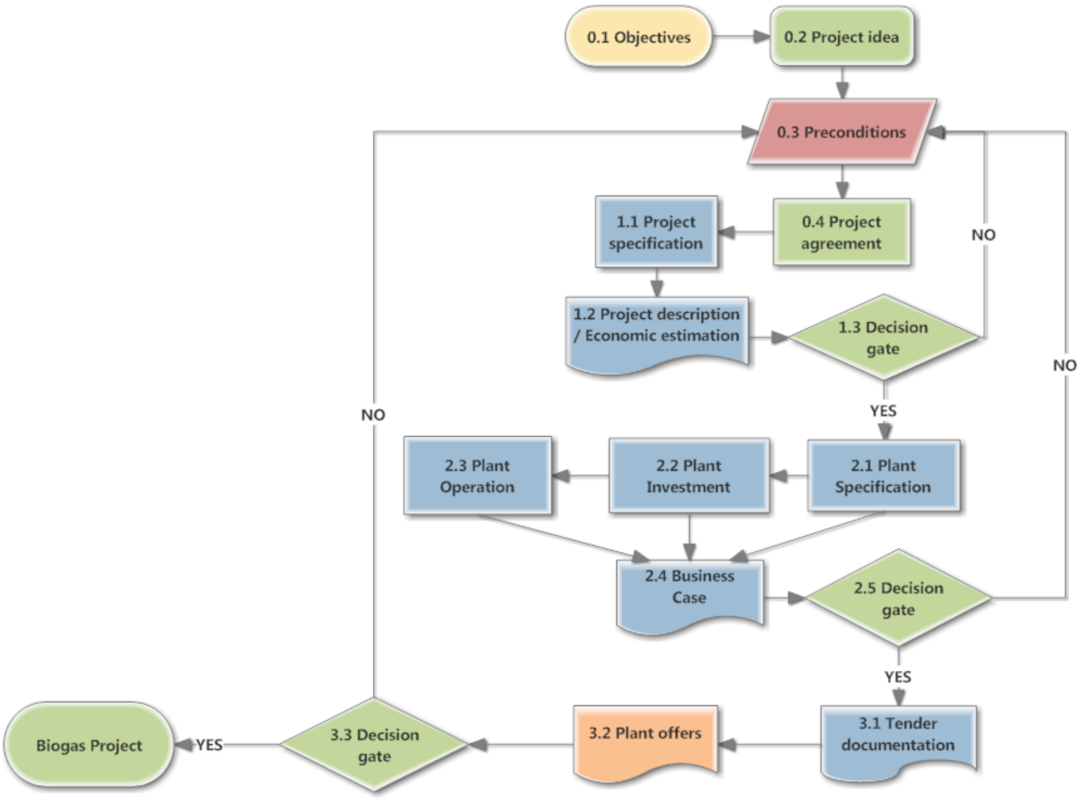


Figure 11 - VFLs approach to biogas projects

Phase 0 – Project start up
The first phase consists of four steps, conducted by the commissioning party, but needed in order for VFL to develop the project.

Step 0.1 – Objectives – The biogas project is based on a range of objectives, which is needed to be known in order to develop the project with the aim of full filling these objectives.

Step 0.2 – Biogas idea – Based on the objectives to for a biogas plant, a biogas idea is created in order to full fill the objectives for the commissioning party.

Step 0.3 – Preconditions – The objectives and biogas idea is limited by the preconditions to the project, which is also defined by the commissioning party.

Step 0.4 – Project agreement – In coherence with VFL is an agreement on the project development made, defining the task for VFL and the commissioning party in the following project phases.

Phase 1 – First business case
The second phase is consisting of three steps, all conducted by VFL, but in close coherence with the commissioning party, in order to develop the project in the right direction.

Step 1.1 – Project specification – All information from phase 0 – Project start up is gathered and documented in or to specify the problem areas in the project that needs solving.

Step 1.2 – Project description and economical estimation – This step describes the project in details, in order to get a common understanding on how the biogas plant should be developed in the project. Also is a calculation on the estimated economy in the project idea conducted, in order to get an understanding on the economy in the biogas project.

Step 1.3 – Decision gate – Based on the findings in step 1.2, the commissioning party decides whether the projects is good enough to continue to the next phase, or if the project should go back to the precondition step, hereby making new preconditions to the project.

Phase 2 – Final business case
The third phase is consisting of five phases, where the first four are highly related to each other. The phase is conducted based on the findings and agreements from the first two phases. The first four steps are conducted by VFL, with the commissioning party conducting the final step of the phase.

Step 2.1 – Plant specifications – The technologies needed in order to handle and extract biogas from the biomass, and to treat the degasified biomass in the best way is found and described. By this specification the plant will be specified for the following steps in the project development. The plant specification will be used in the business case documentation in step 2.4.

Step 2.2 – Plant investment – Based on the specified plant the investments needed for the plant is found. The investment needed is made from defriend scenarios, based on the objective and preconditions, and the rate and payback period available. The findings in this step will be in the business case documentation in step 2.4.

Step 2.3 – Plant operation – The findings in step 2.1 and 2.2, will specify the plant and the investment needed for the plant, which in this step will be used to calculate the operation of the plant, in order to show the economy in the plant. The calculations will be made so they for fill the objectives and preconditions stated in phase 0 – Project start up.

Step 2.4 – Business case – The three first steps in phase 2 – Final business case will be joined in this step, in a business case for the biogas project. The business case will end out in a recommendation from VFL on the biogas plant, from where the commissioning party can take the final decision.

Step 2.5 – Decision gate – From the business case the commissioning party makes a decision on whether the project should continue to the next phase or if the project should return to the precondition step, creating new preconditions for the project.

Phase 3 – Plant offers
This phase is consisting of three phases where the main task is conducted by plant manufactures, with VFL only contributing to the first step.

Step 3.1 – Tender documentation – Based on the specification from the business case and the project specification from phase 1 – First business case, tender documentation over the biogas plant is made. The tender documentation is send to plant manufactures.

Step 3.2 – Plant offers – The tender documentations is used by the plant manufactures to make offers on biogas plants that can be used in the biogas project. The plant offers has to for fill the specifications that are stated in the tender documentation, in order to be found interesting for the commissioning party.

Step 3.3 – Decision gate – The commissioning party compare the plant offers received from the manufactures with the business case from phase 2 – Final business case, in order to assess the offers, and to decide whether the project should be lunched, or if it should be send back to the preconditions step.

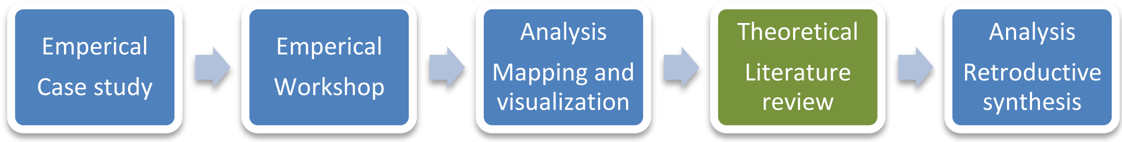
If the final decision gate is accepted and the biogas project is launched, VFLs task in the project development is finished. VFL can be used in future steps of the execution of the project, assessing if the project are on track in relation to the business case accepted in phase 2 – Final business case. If the project is send back to the precondition step from the decision gates, an outcome of this could be a cancelation of the project, if new and improved preconditions to the project cannot be found.

The approach will be used in solving the biogas project suggested in the case study in phase 4 – Business Case of this project. The Sjællandcase is structured after the steps in phase 0 – Project start up, hereby ending out in an agreement on what VFLs tasks are in the continued project. For this project it has been selected to focus on phase 2 – Final business case, due to the fact that this will help answer the research questions about the profitability in the symbiosis.

2.4.4 Interim conclusion

The findings from the two empirical steps, in the research method have now been mapped and visualized in this section. The mapping of the symbiosis and synergy has helped define the two areas further, and the parties that are actors within the two areas. The definition of the symbiosis will now be used, to find relevant literature in the following literature review. The definition of the synergy will help understand the synergy that can be created, and will be used in the discussion on the national political interest towards the symbiosis. Also was the proposed approach to developing biogas projects within VFL found. This will be used in order to structure the goals for the business case, stated by the farmers in the case study.

2.5 LITERATURE REVIEW



During the previous investigations, knowledge about the symbiosis has been found, in order to conduct this literature study, hereby finding the needed literature to answer the research questions.

2.5.1 The symbiosis

This section will investigate literature related to the three main areas found in the symbiosis; the organic farmers, the biogas plant, and the symbiosis between the two parties.

2.5.1.1 Organic farmers

The following will describe the literature found on organic farming in relation to their symbiosis with a biogas plant. The idea of having a symbiosis between organic farmers and a biogas plant is that, the biomasses for biogas production are produced in the organic farmer's crop production, and hereby as a part of their crop rotation. Therefore four areas are found important;

- The gas potential in the biomasses
- The fertilizer potential in the degasified biomass
- The extra yield generated from using degasified biomass as fertilizer
- The relation between biomass production and the crop rotation
-

The biogas potential is important for the biogas plant, whereas the fertilizer, extra yield and the biomasses relation to the crop rotation are important to the farmers. But do to the fact that the biomass is produced by the farmers in their crop rotation, the gas potential and hereby the biogas that can be extracted in the biogas process will also be determined by the farmers and their crop rotation. As found in the case study, the farmers want to continue with their current crop rotation, and the biomasses in the case are therefore found in their current rotation. It is also found important to investigate the relation between biomass and crop rotation further, in order to evaluate the crop rotation in the case.

2.5.1.1.1 Gas potential in the biomass

This section will investigate how the gas potential in the biomasses can be determined, for later use in the calculation of the business case. The gas potential is the total amount of gas that can be extracted from the biomass when being digested in the biogas process, hereby not taking the limiting factors into account, but only on the maximal biogas potential in the biomass. The limiting factors in the biogas production will be investigated in section 2.5.1.2.1 – *Limiting factors in the biogas process*, where it will be investigated how they influence the total output of extracted biogas from the biomass. There is a long range of methods for measuring the gas potential in biomasses (Triolo, Ward, Pedersen, Løkke, Qu, & Sommer, 2013) (Esposito, Frunzo, Liotta, Panico, & Pirozzi, 2012) (Pham, Triolo, Cu, Pedersen, & Sommer, 2013), but common for all these methods is that they need a sample of the biomasses, in order to determine the gas potential. In the case study and the approach of VFL, there is not a sample of the biomasses that can be used in one of the methods, hereby determining the gas potential of the biomasses. Therefore, a method for determining the gas potential theoretically is needed.

When talking about gas potential, and biodegradability, the most relevant indicator that are used is biochemical methane potential, also called BMP, (Lesteur, et al., 2010), which is the amount of methane per unit of volatile solids (VS) (Labatut, Angenent, & Scott, 2010). BMP can although not be directly related to the biodegradability, due to the fact that the VS are containing a range of different organic substances (Triolo, Sommer, Møller, Weisbjerg, & Jiang, 2011), and the different gas potential there is in the substances. BPM is found by calculating the total content of biogas in a biomass that is extracted through anaerobic digestion. Several methods for determining BPM have been developed (Lesteur, et al., 2010) based on a range of different methods, e.g. content of fat, protein and celluloses, but a standard way of determining BPM has not been determined (Angelidaki, et al., 2009).
The method selected for this thesis, is to use Buswell's equation (Ladatut, 2012) to find the molecule weight of the substances in the biomass that are converted into methane. By knowing the weight of the molecules and the amount of the substances in the dry matter (Miljøministeriet - Miljøstyrelsen, 2003) (Ladatut, 2012), the methane potential in the biomasses can be found. In table 11 – *Methane potential in the substances,* the molecule weight of the substances that are in the dry matter can be seen.

Substance	Protein	Fat	Sugar	Strach	Cellulose	Remaining Carbohydrates
Nm3 CH4 per Kg	0,397	1,014	0,373	0,415	0,415	0,415

Table 11 - Methane potential in the substances (Ladatut, 2012)

In table 11 – *Methane potential in the substances* it can be seen that the methane potential in Strach, cellulose and remaining carbohydrates is the same. The reason for this is that all these substances are carbohydrates, but are different in relation to degradability and methane content of the substances. This is also the reason for not having these substances, as one substance. Sugar is also a carbohydrate, but is different than the other carbohydrates in relation to biogas potential (Ladatut, 2012). The degradability and methane content of the substances will be further explained in section 2.5.1.2.2 *degradability and methane content*. The content of the first five substances in the biomasses is found in the feed table from Norfor[18] , and can be found in appendix 9 – NorFor feed table. The content of remaining carbohydrates is the residual fraction of the dry matter content when the five other substances are removed (Miljøministeriet - Miljøstyrelsen, 2003). But not all of the content in the dry matter can be converted into biogas, there is a fraction that are ash, which cannot be converted into biogas (Ladatut, 2012). Therefore, the amount of ash needs to be subtracted from the residual fraction, in order to find the content of remaining carbohydrates in the dry matter. The content of ash in the biomasses can also be found in the feed table from Norfor, which also is highlighted in appendix 9 – NorFor feed table. In straw material there also is a larger fraction that is lignin. Lignin cannot be degraded to biogas unless the biomass is pretreated (Triolo, Sommer, Møller, Weisbjerg, & Jiang, 2011). Therefore is the fraction of lignin needs to be subtracted from the biomass, in order to find the biogas potential in a biomass. The content of lignin is determined to be 40 percent of the full matter weight (Buranov & Mazza, 2008). In table 12 – *Methane potential in the biomasses,* the methane potential for the biomasses in the Sjællandcase can be found.

Biomass	Methane potential	
Unit	**Nm3 CH4 per ton DM**	**Nm3 CH4 per ton FM**
Clover grass silage	396,45	150,25
Straw + clover grass silage	420,90	178,04

[18] Norfor A.m.b.a. – Nordic feed system for evaluation and feeding recommendations for cattle

Seed grass straw	238,30	202,56
Straw	248,46	211,19
Permanent grass silage	395,86	146,86
Carrots + tops	345,19	60,75
Regrown seed grass silage	322,93	112,06
Separated grains	422,11	358,79
Yellow mustard silage	359,06	55,65

Table 12 - Methane potential in the biomasses – Dry matter and Full matter

The biogas potentials are the maximal amount of biogas that can be extracted from the biomasses. But not the full amount of the substances will be converted into biogas during the process. This will be explained further in section 2.5.1.2.2 *degradability and methane content*.

2.5.1.1.2 Fertilizer potential in the degasified biomass

As with the gas potential, the fertilizer potential will also have an influence on which biomasses the farmers will have in their crop rotation (Birkmose, Hjort-Gregersen, & Stefanek, 2013) (Askegaard & Eriksen, 2007). This is due to the fact that the output material from the biogas process, wanted by the farmers, should contain a high amount of nutrients, hereby having good fertilizer abilities (Birkmose, Hjort-Gregersen, & Stefanek, 2013). The fertilizing potential in the biomasses and methods for determining this theoretically, will be investigated.

The amount of fertilizer in the degasified biomass is determined based on the input material in the biogas process (Ministry of Food, Agriculture and Fisheries, 2013). The fertilizing efficiency is determined by the input fertilizer, if the biomass mixture consists of a mixture of different fertilizers. As the case was for determining the gas potential, many methods can be used in order to find the potential (Raju, Løkke, Sutaryo, Ward, & Møller, 2012). In the case of determining the amount of fertilizer that is the maximal potential, NorFor's[19] feed table can be used. The feed table contains data about the content of all the relevant nutrients in relation to the fertilizer potential, and can therefore be used in order to determine the amount of nutrients in the degasified biomass. In table 13 – NPK *content in the biomasses from the Sjællandcase* the nutrient content for the biomasses in the Sjællandcase can be seen.

Biomass	Kg Total – N per ton	Kg NH4 – N per ton	Kg Organic – N per ton	Kg P per ton	Kg K per ton
Organic					
Clover grass silage	9,88	0,53	9,35	1,25	9,59
Straw + clover grass silage	8,06	0,31	7,75	1,02	11,58
Seed grass straw	9,11	-	9,11	0,94	12,75
Straw	5,44	-	5,44	0,68	14,45
Permanent grass silage	9,02	0,69	8,34	1,37	10,39
Carrots + tops	2,68	-	2,68	0,33	4,01
Regrown seed grass silage	8,99	0,59	8,40	1,08	10,24
Separated grains	14,42	1,44	12,97	2,89	5,02
Yellow mustard silage	4,06	-	4,06	0,64	4,42
Cattle deep straw	8,50	1,50	7,00	2,50	5,00
Cattle slurry	3,50	1,45	2,05	0,80	3,20
Cattle manure	8,50	1,50	7,00	2,50	5,00

19 NorFor – Nordic Feed Evaluation System

Conventional					
Pig slurry	4,00	2,40	1,60	0,90	1,60
Cattle deep straw	8,50	1,50	7,00	2,50	5,00
Pig manure	11,00	3,00	8,00	4,00	5,00
Poultry manure	20,77	3,00	17,77	7,00	2,00
Cattle slurry	3,50	1,40	2,10	0,80	3,20

Table 13 - NPK content in the biomasses from the Sjællandcase

A factor that cannot be predicted before knowing the technology that will be used, and the final content of biomasses for the biogas plant, is the substance form. The substance form will have an influence on the fertilizer utilization of the degasified biomass (Petersen & Sørensen, 2008), and studies have even shown that the use of fertilizer as compost can improve the soil significantly (Hepperly, Lotter, Ulsh, Seidel, & Reider, 2009), compared to e.g. manure. This has although not been proven in the yield and food quality in the crops, and is therefore not something that will be taken into consideration in the further study. Studies comparing the use of regular slurry, pig and cattle, and degasified slurry on similar soil and crops have shown an increase in N utilization of ten percent compared to pig slurry and 20 – 30 percent for cattle slurry (Knowledge Centre for Agriculture, 2011). The utilization of the fertilizer in the degasified biomass will be investigated further in the following section.

2.5.1.1.3 Using degasified biomass as fertilizer

In order to investigate this area, knowledge on the nutrients needed by the plants in organic farming will be investigated in order to determine the factors that should be used when determining the yield response. Hereafter, the yield will response from using degasified biomass as fertilizer found for the crops in the crop rotations in the Sjællandcase. Ending off this section will the legislations related to using degasified biomass as fertilizer in organic farming be investigated.

2.5.1.1.3.1 Nutrients needed in organic farming

As found in the introduction, the nutrient that is most important in farming and especially organic farming is nitrogen (N) (Ladha, Pathak, Krupnik, Six, & Kessel, 2005) (Zafari & Kianmehr, 2012) . Two other nutrients are also important for the soil and crops in order to maintain a high yield and an environmental sustainability. The two nutrients are phosphorus (P) and potassium (K) (Foissy & Vian, 2014). Therefore, this section will investigate the importance of the three nutrients in organic farming, and their effect on the yield response to the three nutrients being used as fertilizer.

Nitrogen (N)

The crops demand for nutrients and particularly N is rated as the fourth limiting factor for a plants growth, rated behind solar irradiance, temperature and water (Ladha, Pathak, Krupnik, Six, & Kessel, 2005). The reason for these factors to have a greater impact is due to their influence on photosynthesis and respiration processes (Ladha, Pathak, Krupnik, Six, & Kessel, 2005). All factors concerning the crops demand, supply and losses for nutrients, and hereby N, is related to each other, and will have an effect on each other. The factors related to crops demand, supply and losses can be seen in figure 12 – *Nitrogen in the crop production*.

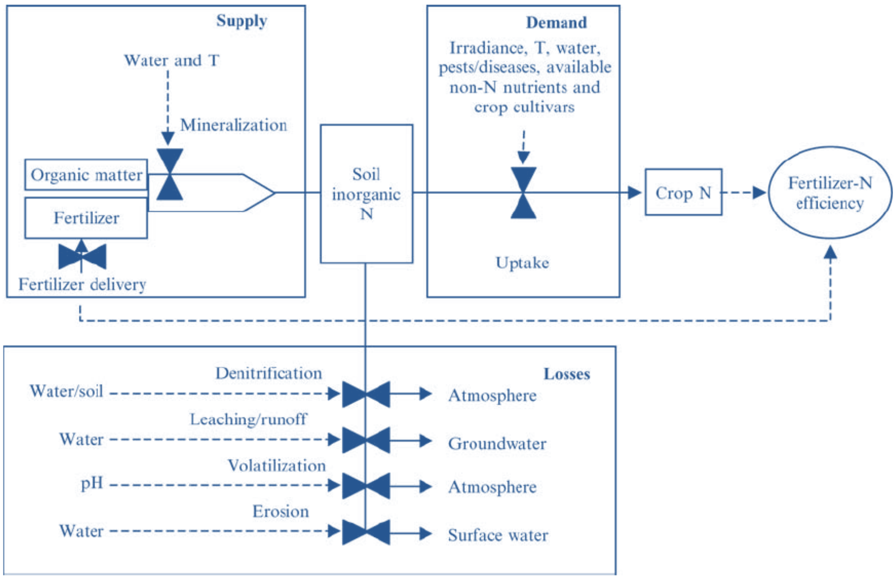


Figure 12 - Nitrogen in crop production (Ladha, Pathak, Krupnik, Six, & Kessel, 2005)

As seen in figure 12 – *Nitrogen in the crop production,* the three areas are related and will determine the efficiency of the fertilizer and hereby also the loss of N. Nitrogen can be divided into two areas, organic nitrogen (Protein) and inorganic nitrogen (Ammonium) (DLBR, 2000). Where organic nitrogen is the protein related nitrogen, that are slowly degraded and hereby hard absorbable for the plants, while inorganic nitrogen is the ammonium related nitrogen, that is easily absorbable for plants, due to the content of a positive electron (Ladha, Pathak, Krupnik, Six, & Kessel, 2005). Organic nitrogen can be stored in the soil, while much of the inorganic nitrogen will be leached if not absorbed by the plants (DLBR, 2000). The amount of fertilizer that will be absorbed by plants is therefore determined by the content of organic and inorganic nitrogen in the fertilizer (DLBR, 2000).

The natural supply of N is coming from the soil organic matter, where the rest needed, in order to meet the demand is provided from fertilizer (Ladha, Pathak, Krupnik, Six, & Kessel, 2005). The organic matter (hereby organic nitrogen) needs transformation through mineralization before becoming available for the crop. Mineralization is a slow process that is highly dependent on the content of carbon (C) in the soil, which leads to need for a dynamic relation between the content of C and N in the soil (Stevenson, 2001) (Hepperly, Lotter, Ulsh, Seidel, & Reider, 2009). Fertilizer is often applied in a form, where from the main part of the N content is easily available for the crop (Ladha, Pathak, Krupnik, Six, & Kessel, 2005). But related to both ways of supplying N (Organic matter in the soil and added fertilizer) is the loss of N. This is related to the efficiency of N, and hereby the balance that should be created in order to get a good efficiency (Fageria & Baligar, 2005). An area found important related to this management, is using fertilizer during the growing season, hereby raising the efficiency and reducing the loss (Knowledge Centre for Agriculture, 2012). The loss of N is not only a hazard for the environment, but is also an economical expense for the farmers (DLBR, 2000), due to the lower effect of the fertilizer.

Phosphorus (P)

Plants are in need of phosphorus in order to grow, since phosphorus is an important part of many chemical bindings in plants and animals (DLBR, 2008). Therefore, a low content of phosphorus will lead to a bad growth of the plants, and if used as feed for livestock, missing phosphorus in the livestock (DLBR, 2008). Phosphorus is absorbed by plants through soil fluids, but the content here is very low. As with nitrogen, phosphorus is released to the soil fluids by mineralization from the soils content of organic matter. In the organic matter is phosphorus bound with other substances (Videncentret fo Landbrug, 2012). A surplus of phosphorus in the soil is not as large an environmental hazard as a surplus of nitrogen is, due to lower possibility for leaching of nitrogen (DLBR, 2008). This is because phosphorus is easily bound to other substances in the soil, and can hereby be absorbable when the plants need it. But a too large surplus of phosphorus will lead to leaching into the ground water (DLBR, 2008).

Soil type	Unit	Winter cereal	Spring cereal	Grass seed	Clover grass
Sandy soil	Yield hkg/ha	52	41	8	72
	Remov. kg P/ha	18	15	9	28
Clay soil	Yield hkg/ha	83	59	15	90
	Remov. kg P/ha	27	22	15	34

Table 14 - Amount of phosphorus removed related to the soil type (DLBR, 2008)

A general rule is that the amount of phosphorus that are removed when harvesting the crops, should be added to the fields, in order to have a balance in the content of phosphorus (Videncentret fo Landbrug, 2012).

Potassium (K)

As for nitrogen and phosphorus, potassium is rated as one of the most important nutrients for the plants and animals (Knowledge Centre for Agriculture, 2009). Potassium is important for the plants in order to avoid a range of growth difficulties, among these drought, low temperatures and pest infestation (Videncentret for Landbrug, 2012) (Öborn, Andrist-Rangel, Askekaard, Grant, Eatson, & Edwards, 2005). Potassium deficiency can lead to drought in the plants, due to potassium having an effect on the plants ability to absorb water, hereby also the uptake of other nutrients like nitrogen. Potassium will also make the plants resistant towards low temperature, which will make them more able to survive a winter with low temperatures. Therefore, potassium is, as a fertilizer, often provided to the plant during fall, hereby increasing the survival of the plants during winter (Knowledge Centre for Agriculture, 2009) (Videncentret for Landbrug, 2012). As for phosphorus is potassium storage in the soil (Knowledge Centre for Agriculture, 2009). The supply that is needed by crops is different, based on the sort of plants (Öborn, Andrist-Rangel, Askekaard, Grant, Eatson, & Edwards, 2005). Cereals have a very good ability of absorbing potassium, and are only in need of a little amount, which easily can be absorbed from the soil. Legumes and catch crops, like peas and clover, is not good absorbers of potassium and is in need of a greater amount, therefore these plants are in need of a supply of fertilizer potassium. In addition, the different types of soil have an influence on the content of potassium, due to the soils ability to bind and hold the nutrient (Knowledge Centre for Agriculture, 2009). Clay soil is much better at this than sandy soil, therefore is there a need for adding more potassium for crops on sandy soil than on clay soil.

As found in this section, the nitrogen is the important factor for determining the yield response over a period of time that is a year. On the other hand, potassium and phosphorus have an impact on the crop yield over a longer period. Therefore, it is concluded, based on the findings, that nitrogen is used in order to determine the crops yield response to fertilizer, but that potassium and phosphorus will be used in order to evaluate the yield response over a longer period.

2.5.1.1.3.2 Yield response to fertilizer

The object of this section is to find a theoretical way of determining the yield response to using degasified biomass as fertilizer. As found through the investigation about nutrient need in organic farming, a range of factors have influence on the crop and hereby the yield and food quality in the crops, e.g. solar irradiance, temperature, water and soil type. Other factors such as the crop rotation (DLBR, 2006) the kind of fertilizer used (Hepperly, Lotter, Ulsh, Seidel, & Reider, 2009), and the crop yield response to NH4-N (Knowledge Centre for Agriculture, 2013) will in addition have an impact on the yield output. The factors that will be taken into consideration in this project will be the selected crop, the soil and the crop yield response to NH4-N. These three factors will be selected, knowing that the other factors also have an influence. The other factors will be left out of further considerations, since their impact is too complex to determine (Knowledge Centre for Agriculture, 2013).

When determining the fertilizing supply on a farm it is important to know that the crops yield response to fertilizer is highest at a low level of fertilizer supply (Knowledge Centre for Agriculture, 2013). Therefore, it is important to look at the crops yield response to fertilizer when planning the fertilizer supply on the farm. The crops selected for this investigation is the yearly crops that are generating yield once every year. The fact for selecting these crops for the investigation is that these crops are generating the highest income for the farmers (DLBR, 2014). This can be seen in the figure 13 – *Crop yield response to NH4-N*.

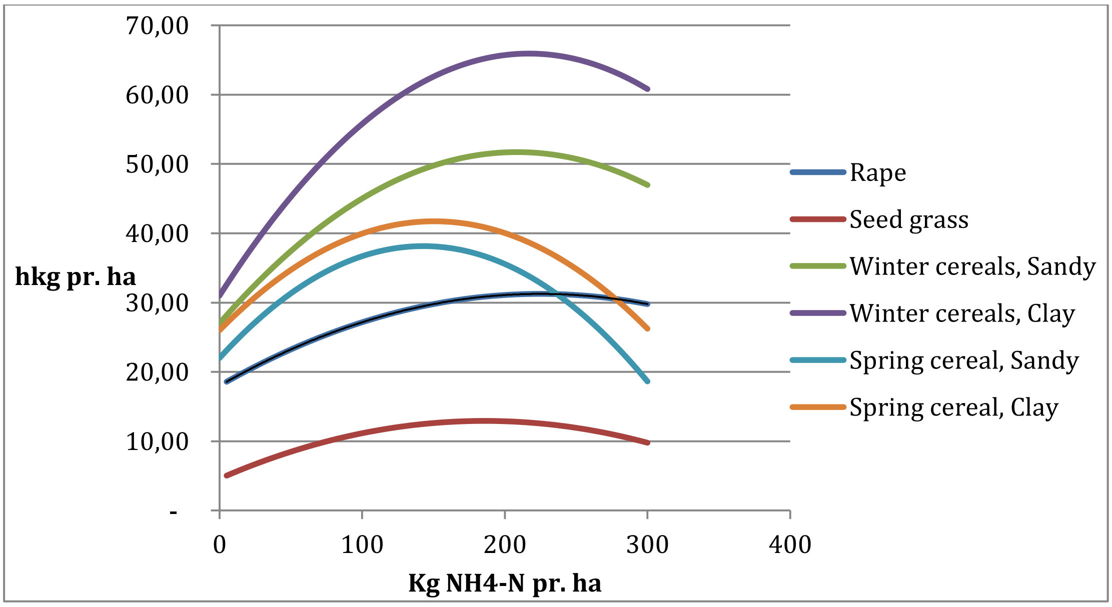


Figure 13 - Crop yield response to NH4-N (Knowledge Centre for Agriculture, 2013)

Based on figure 13 – *Crop yield response to NH4-N,* it is found that the yield response is highest for winter cereals. The yield response is found based on annual yield response trials, performed by VFL. Nevertheless, it is a fact that the crop prices are different for the crops where yield response has been investigated. This factor needs to be taken into consideration when determining which crop that generates the best earnings based on the response to the use of NH4-N (Knowledge Centre for Agriculture, 2013). The prices for the crops can be found in table 16 – *Crop prices*.

Crop	Kr. per kg	Kr. per hkg
Spring cereal	2,20	220
Winter cereal	2,00	200
Rape	6,50	650
Seed grass	11,00	1.100

Table 15 - Crop prices (DLBR, 2014)

In figure 14 – *Extra earnings generated from the use of NH4-N,* the extra earnings generated from using NH4-N as fertilizer can be seen.

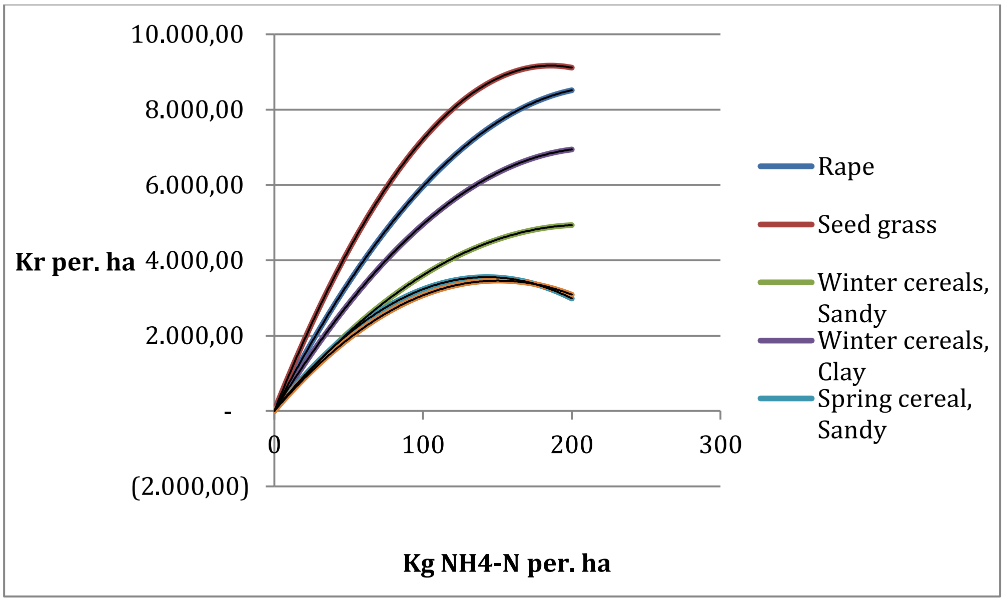


Figure 14 - Extra earnings generated from the use of NH4-N

As seen, seed grass and winter rape are found to be the crops that should be given the highest amount of fertilizer, due to these crops generating the highest earnings. In addition to finding the profitability of using degasified biomass as fertilizer are the costs of spreading the fertilizer on the fields. The cost for this can be found in table 16 – *Price for spreading fertilizer*.

Fertilizer substance	Solid	Fluid
Price	35 kr. per ton	25 kr. per ton

Table 16 - Prices for spreading fertilizer (DLBR, 2013)

2.5.1.1.3.3 Legislation towards using degasified biomass as fertilizer

The legislations towards degasified biomass are a part of the fertilizer legislations in organic agriculture, due to the substance status as fertilizer (Ministry of Food, Agriculture and Fisheries, 2013). In order for the degasified biomass to have the status of organic fertilizer, all biomasses for the plant need to be organic. If conventional biomasses are used in the biogas production, the biogas plant needs an approval from NaturErhvervstyrelsen[20] in order to classify the degasified biomass as partly or fully organic (Ministeriet for Fødevarer, Landbrug og Fiskeri, 2014). A plant getting the classification as partly organic should follow the rules of organic fertilizer regarding degasified biomass. This meaning that the amount of non-organic biomass that is used counts as part of the 70 Kg N-tot per ha per year, which are allowed to be used (Ministeriet for Fødevarer, Landbrug og Fiskeri, 2014). In addition, there are rules enforcing that documentation is needed (Ministeriet for Fødevarer, Landbrug og Fiskeri, 2014), showing the amount of non-organic and organic content in the degasified biomass. If a biogas plant does not have status as an organic biogas plant, the degasified biomass is rated as conventional fertilizer, and the rules of this are enforced. All biogas plants are obligated to document the content of fertilizer in the degasified biomass, which is done based on 12 annual tests, tested in in a laboratory that is approved to conduct these tests (Ministry of Food, Agriculture and Fisheries, 2013).

20 http://naturerhverv.dk

2.5.1.1.4 Biomass in the crop rotation

The parameters in relation to the gas and fertilizer potential have been identified. Therefore, knowledge regarding the biomass for biogas production in the crop rotation can be found. The introduction introduced a range of parameters that have influence on the crop rotation in organic agriculture, and these will have an influence on the biomasses that are available for biogas production. However, due to the use of biomasses for biogas production and later for fertilizing, the gas and fertilizing potential will also have an influence on which crops should be in the crop rotation. From the farmers perspective, especially the fertilizing potential in the biomass is important (Knowledge Centre for Agriculture, 2012), due to the yield response found.

In order to incorporate the biomasses in the crop rotation, there is a range of possibilities, the important factor is although to select crops with the ability to collect nutrients (Knowledge Centre for Agriculture, 2012), especially nitrogen. Having crops for biomass in the crop rotation gives the farmers other tools against weeds, where the biomass crop can be seeded and harvested in an unregularly cropping period. A way of producing nutrient rich biomass crops, is by having catch crops in the interval between two primary crops (Molinuevo-Salces, Larsen, & Ahring, 2013), hereby producing a biomass crop and doing weed control. The suggestion from VFL (Knowledge Centre for Agriculture, 2012) for a crop rotation is to have a main crop that is nitrogen fixated and does not need fertilizer, and to select catch crops that have a short growth period. Another aspect that is found important from VFL is the cost for producing the biomass. Due to the fact that the crops for biomass are not the primary crops in the crop production, the aim is to keep the cost for producing the biomass as low as possible.

Biomass can also be produced alongside the regular feed and food crops, hereby being energy crops due to the use for energy production. Nevertheless, this production of energy crops is leading to a discussion about using farmland for energy production at the expense of food production, when hunger is rated as a world problem (Muller, 2009) (Valentine, Clifton-Brown, Hastings, Robson, Allison, & Smith, 2012). Another issue is, that the energy crop needs to generate revenue that is at minimum the same as the primary crop production (Jørgensen, et al., 2013), which will increase the purchase price for the biogas plant, and make their profitability harder.

Residues from the primary crop production can also be used as biomass in a biogas production, e.g. straw from cereals and seed grass (Svensson, Christensson, & Björnsson, 2005). An aspect that needs to be taken into consideration when using residues from the crop production in biogas production is the impact the residues have to the soil condition (Neill, 2011). Especially the content of Carbon and hereby the relation between C and N. Removing the residues could therefore have a highly negative impact on the soils ability to transform organic matter into nutrients for the crops.

2.5.1.2 The biogas plant

This section describes the literature found on the biogas plant, and the factors essential for the biogas plant in the symbiosis with organic farmers. The general biogas process was found in the introduction, and it will be the basis for this section. The first sub-section describes the literature on the limiting factors to the biogas process. The second sub-section will describe the degradability and methane content generated from the degasification of the biomasses. The third sub-section will contain an investigation of the transformation of nitrogen in the biogas process. The fourth and last sub-section will describe the handling of biomasses in the biogas process.

2.5.1.2.1 Limiting factors in the biogas process

There is a range of factors that are influencing the production of biogas, hereby being the limiting factors to the amount of biogas produced. Therefore, all of these factors will determine the amount of potential biogas that are converted into methane and hereby biogas (Jørgensen P. J., Biogas - Green Energy, 2009). All of the factors have a relation to each other and they will therefore determine the degradability of the organic substances, and the content of methane in the produced biogas. The factors are divided into two areas, physical factors and inhibition factors. The relation between the two areas is that both areas are determined by the biomass that is being processed (Artanti, Saputro, & Budiyono, 2012).These two areas will be described in the following sections.

2.5.1.2.1.1 Physical factors

As described the physical factors are determined by the biomasses that needs to be processed in the biogas plant, which means that the composition of biomasses also is a determining factor. Due to biogas being produced through an anaerobic process the first factor is the fact that the environment of the process needs to be oxygen-free (Jørgensen P. J., Biogas - Green Energy, 2009) (Mattocks, 2002). Temperature in the reactor tank is influencing the bacteria's ability to degrade the biomass (Chen, Cheng, & Creamer, 2007), doubling the process rate for every 10-degree rise in temperature (Jørgensen P. J., Biogas - Green Energy, 2009). Increasing the temperature also increases the level of sensitivity of the bacteria, which are highly sensitive to the change in temperature. Biogas processes are often run at 37 degrees (Mesophil), where the bacteria are sensitive to a degree change of 2 degrees, or at 52 degrees (Thermophil) where the bacteria are sensitive to a degree change of 0,5 degrees. The bacteria's are not only sensitive to temperature, but also to pH level in the biomass (Chen, Cheng, & Creamer, 2007). The bacteria's are feeding on organic acids for some of their food intake, but despite this, they cannot live in an environment that is too acid (Chen, Cheng, & Creamer, 2007). Therefore there is a need for a balance in the process, where the level of acid is just enough for the bacteria´s to feed from. This is normally on a pH level between 6.5 and 8 (Jørgensen P. J., Biogas - Green Energy, 2009) (Mattocks, 2002). As mentioned the bacteria are feeding from acids, but this is not the most important feed for them. The most important nutrients for the bacteria are Nitrogen (N), Phosphorus (P) and Potassium (K) (Jørgensen P. J., Biogas - Green Energy, 2009). These nutrients need to be present in order for the bacteria to grow, but to high content will inhibit the process. In figure 15 – *Nutrients stimulation and inhabitation on the biogas process*, an example on a nutrient's influence on the process can be seen. This will also be investigated further in the following section.

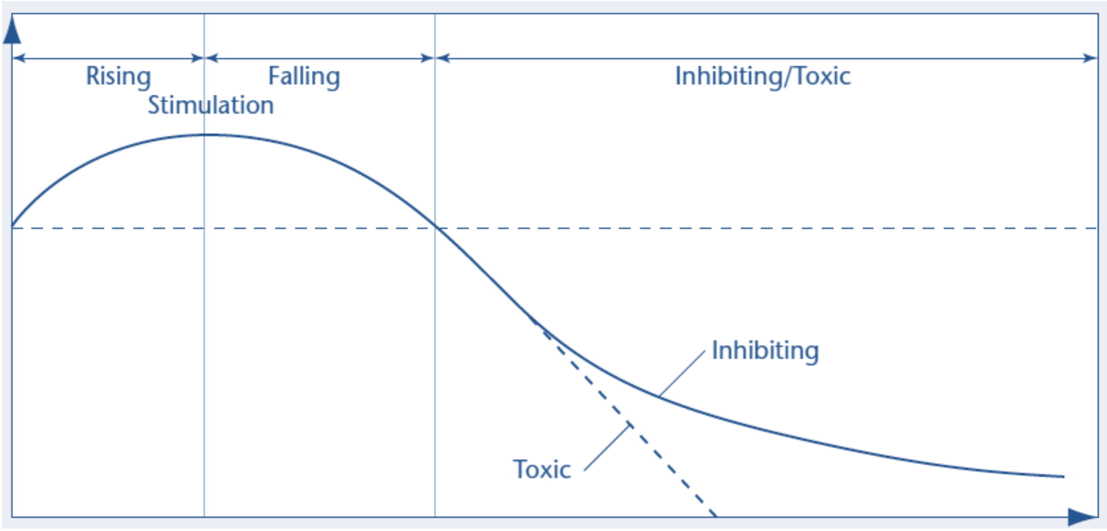


Figure 15 - Nutrients stimulation and inhabitation on the biogas process (Jørgensen P. J., Biogas - Green Energy, 2009)

The rate at which the biomass is added, and removed from the reactor has to be adjusted to the growth of the bacteria, and hereby their ability to convert organic matter to biogas (Jørgensen P. J., Biogas - Green Energy, 2009). The rate of this will also determine the acid level in the reactor, if more biomass is added than the bacteria can degrade, the process will become acid, and inhibit the biogas production. Therefore it is important that the biomass is added at an even rate and volume, over a continuously interval. In addition to the rate of feeding the biomass is the stirring and comminution of the biomass. The biomass needs to be stirred in order to avoid developing an impenetrable surface crust (Jørgensen P. J., Biogas - Green Energy, 2009) (Ward, Hobbs, Holliman, & Jones, 2008), enabling the biogas to leave the biomass. The bacteria are attacking the surface of the material, therefore are the biomasses needed to be comminuted, in order to make as big a surface as possible for the bacteria (Eggert, 2011). This can be done at several places in the process, e.g. pre-treatment, reception tank and pump station, with a range of different methods. This area will be further investigated in section 3.1.2.3 – The biomasses in the biogas process.

2.5.1.2.1.2 Inhibition factors

As mentioned shortly in the previous section, the content of nutrients can both be stimulating and limiting for the process. Many of the nutrients are used as feed for many of the bacteria, but too great content of them will be inhibit to the process. The most significant inhabitation is from ammonia (NH3) and ammonium (NH4), which is created during the degradation of nitrogen, by the bacteria in the process (Hansen, Angelidaki, & Ahring, 1998) (Chen, Cheng, & Creamer, 2007). As mentioned nitrogen is an important nutrient for the bacteria, but too high content is inhibit to the bacteria's (Møller, 2006). Related to the content of ammonia are the temperature and pH level in the process, which is influencing the balance between ammonium (NH4) and toxic ammonia (Jørgensen P. J., Biogas - Green Energy, 2009). This relation can be seen in figure 16 – *Balance between ammonium and ammonia*, where from the bacteria's sensitivity to temperature and pH change also can be seen.

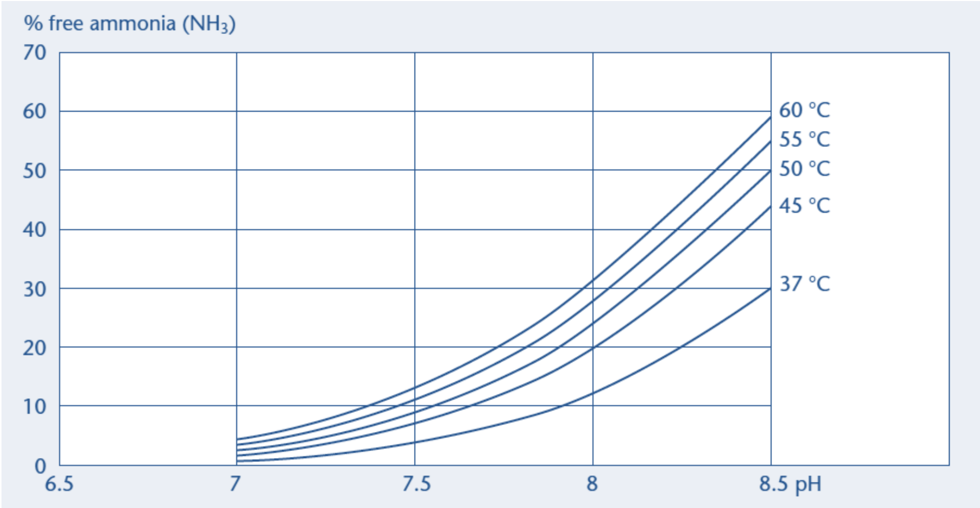


Figure 16 - Balance between ammonium and ammonia

The aim of the process is to have a balance between the ammonium and ammonia, because the bacteria are highly sensitive to a sudden change in the concentration (Hansen, Angelidaki, & Ahring, 1998). This is related to the rate of biomass that is applied to the process, which is needed to be continuous, in order to avoid the sudden change in the balance. Organic acid is also rated as an inhibitor with influence on the production of biogas (Jørgensen P. J., Biogas - Green Energy, 2009). Organic acid is produced during the process, and is related to an overload of the process, where from the acid is generated. Of other substances that are inhibiting to the process in high concentrations are heavy metals, salts and micronutrients. In table 17 – *Inhibition level for selected substances,* the inhibition level of a range of substances can be seen.

Substance	Chemical name	Inhibition level
Ammonia	NH3	0,05 – 0,1 kg N/m3
Ammonia + ammonium	NH3 + NH4	1 – 6 kg N/m3
Chloride	CL	< 8 kg/m3
Sodium	Na	3 – 10 kg/m3
Calcium	Ca	8 kg/m3
Magnesium	Mg	3 kg/m3

Table 17 - Inhibition level for selected substances (Jørgensen P. J., Biogas - Green Energy, 2009)

A concentration that is exceeding the inhibition limit is found to be toxic to the process, and will kill bacteria's in the environment. The content in table 17 – *Inhibition level for selected substances,* is only a limitation related to the general plant, and will therefore not be specific for every plant (Jørgensen P. J., Biogas - Green Energy, 2009), but the table will give an overview over the substances and the inhibition level.

2.5.1.2.2 Degradability and methane content

The degradability of the substances in a biomass is highly related to the factors that are determining the process, such as process time and process temperature. But the most important factor is the biomass, and the content of methane containing substances in the biomass. In section 2.5.1.1.1 – *Gas potential in the biomass* the substances, that are containing methane were found, and therefore the production of biogas can be determined by looking at the degradability and methane content of the substances. Therefore it has been selected to use the knowledge found in a project conducted by DTU[21] (Miljøministeriet

[21] DTU – Danish Technical University

- Miljøstyrelsen, 2003), where the degradability and methane content of the substances have been found (Jørgensen P. J., Biogas - Grøn energi, 2009) (Ladatut, 2012). In table 18 – *Degradability and methane percent in the substances,* below, the degradability percentage of the substances in the biomass can be found, related to the two process temperatures that are most commonly used in biogas plants.

Substances	Protein	Fat	Sugar	Starch	Cellulose	Remaining Carbohydrates
Mesophilic						
Degradability (%)	76	96	87	46	80	53
Thermophilic						
Degradability (%)	83	100	84	65	87	66

Table 18 - Degradability and Methane percent in the substances (Ladatut, 2012)

As seen in table 18 – *Degradability and methane percent in the substances*, the degradability of the substances are different, even the substances that all are carbohydrates (Strach, cellulose, sugar and remaining carbohydrates). This is due to the fact that the bacteria degrading the substances have a harder task of degrading some of the substances, which will determine the degradability of the substance (Ladatut, 2012). As described in sub-section 2.5.1.2.1.2 – *Inhibition factors*, an increase in process temperature will make the growth rate of the bacteria's faster, which will lead to more of the substances being degraded during the process (Jørgensen P. J., Biogas - Green Energy, 2009). Another aspect that is related to the amount of methane, and hereby biogas, that are produced is the content percentage of methane in the gas that are extracted from the biomasses. Again this is related to the substances in the biomasses that are degraded to methane during the process (Jørgensen P. J., Biogas - Green Energy, 2009). The methane content percentage from the substances can be found below in table 19 – *Methane content from degrading the substances*.

Substances	Protein	Fat	Sugar	Starch	Cellulose	Remaining Carbohydrates
Methane (%)	63,6	70,2	50	50	50	65

Table 19 - Methane content from degrading the substances (Jørgensen P. J., Biogas - Green Energy, 2009)

2.5.1.2.3 Transformation of Nitrogen in the process

During the biogas process nitrogen is converted from organic nitrogen, to inorganic nitrogen, due to the bacteria's feeding from the organic nitrogen (Møller, 2006) (Sørensen, Khan, Møller, & Thomsen, 2012). The level of ammonium that is converted during the process, is related to the mineral content in the biomass that is treated in the biogas plant, and the technologies and methods used in the biogas plant (Sørensen, Khan, Møller, & Thomsen, 2012). Studies show that digested biomass from crops will release a higher amount of ammonia to the soil than untreated crop biomass (Sørensen, Khan, Møller, & Thomsen, 2012). Following these studies, it is found that an amount of approximately 50 percent is converted from organic to inorganic N, during treatment of biomass in a biogas plant (Knowledge Centre for Agriculture, 2014). Therefore the utility percentage of the fertilizer will be determined by the content of ammonium nitrogen in the degasified biomasses.

2.5.1.2.4 Handling the biomasses in the biogas process

As described in the section 2.5.1.2.1 – *Limiting factors in the biogas process*, the biomass processed in the biogas process is determining the limitations to the process. Therefore, the biomasses used in the process and the methods of handling them are essential, in order to

make the process work as optimal as possible. As mentioned in section 2.5.1.2.1.1 – *Physical factors*, the bacteria need a surface as big as possible, in order to have the optimal growth, which is done by comminution of the biomasses in the process (Eggert, 2011). The surface area is not the only reason for comminution of the biomasses. Comminution is also needed in order for pumps to be able to pump the biomass through the process (Ward, Hobbs, Holliman, & Jones, 2008), if using wet anaerobic digestion as the biogas process. But this is not the only way of treating the biomass in order to increase the surface and hereby increase the biogas production. A range of pre-treatment methods are available (Ward, Hobbs, Holliman, & Jones, 2008), e.g. thermal pre-treatment (Tanaka & Kamiyama, 2002), or ultrasonic pre-treatment (Kim, Gomec, Ahn, & Speece, 2003). The pre-treatment solutions will increase the production of biogas, but they are in many cases highly technical and difficult to use in a production plant (Ward, Hobbs, Holliman, & Jones, 2008). But the issue that is rated highest when selecting a method for comminution and pre-treatment, is the costs related to the use of the methods (Kim, et al., 2003). Therefore, it is vital to find the right relation between the costs of the methods used, what is needed for the biomass to work in the process, and the biogas that can be extracted using the method.
An issue that is related to the handling of the biomasses and the need for comminution and pre-treatment in the biogas process is the pre-treatment that can be conducted during harvest of the biomasses, or during storage of the harvested biomasses. This topic will be investigated in section 2.5.2.1.1.2 – *Issues related to the handling and transportation*.

2.5.2 The Symbiosis

This section will describe the literature found in relation to the findings about the cooperation between the two parties in the symbiosis. The symbiosis is the relations and factors that are needed in between the organic farmers and biogas plant, in order for the cooperation to work in the best possible manner. The first sub-section will contain the literature found in relation to finding a location to the biogas plant, among these the costs for transportation, the sales options to the produced energy and the local acceptance of the location. The second sub-section will contain the legal issues related to the symbiosis, hereunder the permission to build the plant and the bindings needed in the cooperation between organic farmers and biogas plant.

2.5.2.1 Location of the plant

This sub-section will investigate the factors that are important in relation to the location of the plant. Three areas have been found and investigated, Transportation and handling of the biomasses, Sales options to the produced biogas and Local acceptance of the location.

2.5.2.1.1 Transportation and handling of the biomasses

This area will be divided into two areas, the first investigates the costs related to transportation and handling the biomasses between farmer and biogas plant, the second the handling issues that are related to the transportation and handling of the biomasses.

2.5.2.1.1.1 Cost for transportation and handling

The costs for harvesting, handling, storage and transportation of the biomasses before and after the biogas process, are found to have an extensive influence on the optimal location of the plant (Innovationsnetværket for Biomasse, 2010). The costs of the transportation and handling the biomasses will very much influence the economy in the symbiosis. The biomasses from the Sjællandcase can be divided into three groups, solid biomass from silage and manure, solid biomass from straw bales and fluid biomass from slurry. Therefore, the investigations will be focusing on finding the costs related to the transportation and handling of these three groups.

The first action related to the handling of the biomasses is to harvest the crops at the farmer, hereby turning it from crops into silage or straw, relative to which crop is harvested. The costs for harvesting the silage crops are 1.025 kr. per ha (DLBR, 2013), and the costs for making straw into bales are 145 kr. per ton (DLBR, 2005). Afterwards, the question is whether to storage the biomass at the farm, or transport it to the biogas plant. The storage capacity at the farm and biogas plant will help determine this. But a fact that needs to be taken into consideration is the loss of nutrition (Sørensen P. , Gødningsvirkning og håndtering af mobil grøngødning, 2012), and hereby fertilizer and biogas potential, each time the biomass needs to be handled. Therefore, the recommendation is only to handle and transport the biomasses after producing it, storing the biomass at the biogas plant until use (Jørgensen T. V., 2012), hereby minimizing the costs and losses of nutrition in the biomasses. Also, there are costs related to the handling of the biomasses each time they need to be loaded for transportation (Jørgensen T. V., 2012), which will increase the costs of handling the biomasses. The handling costs for loading and unloading the straw bales are 20 kr. per ton (Knowledge Centre for Agriculture, 2013), and the costs for storage are 60 kr. per ton (DLBR, 2005). The costs for loading silage crops are 6 kr. per ton (Larsen & Maegaard, 2010), and the costs for storage are 31,33 kr. per ton (Knowledge Centre for Agriculture, 2010). The storage costs of slurry are estimated to be 15 kr. per ton (Videncentret for landbrug, 2010).There are no loading costs related to the transportation of slurry, due to the trucks being self-loading, therefore the loading costs are incorporated in the transportation cost (Agro tech, 2007).

The costs of storing the biomasses are the lowest that could be found, which has been selected due to the fact that transportation and handling is known to be a big economical factor in cooperation between farmers and biogas plant (Innovationsnetværket for Biomasse, 2010). The last costs related to the handling of the biomasses before the biogas process, are the transportation of the biomasses. Due to the long distance in-between the three farms (more than 10 km) in the Sjællandcase, the biomasses are expected to be transported by trucks. The costs for transporting the biomasses are defined kr. per ton per km. The costs for transporting silage crops are 1,18 kr. per ton (Larsen & Maegaard, 2010), while the costs for transporting straw bales are 1,35 kr. per ton. The cost for transporting slurry are 1,01 kr. per ton per km (Agro tech, 2007). In table 20 – *Costs for handling and transportation of the biomasses,* the cost related to the two groups of biomasses can be seen.

	Solid Straw	Solid Silage	Fluid Slurry
Harvest	174 Kr. per ton	1.025 Kr. per. ha	0
Loading/unloading	20 Kr. per ton	6 Kr. per ton	0
Storage	60 Kr. per ton	31,33 Kr. per ton	15 Kr. per ton
Transportation	1,35 kr. per ton per km	1,18 kr. per ton per km	1,01 kr. per ton per km

Table 20 - Costs for handling and transportation of the biomasses

There are also handling and transportation costs related to the degasified biomass. These are related to the transportation of the degasified biomass back to the farmers and storage. Because the degasified biomass can be on different mediums, related to the type of plant selected, the costs for the transportation will be different. The degasified biomass can be two substances, solid or fluid. The solid degasified biomass is similar to the solid silage, and the cost of this is found to be the same. The fluid degasified biomass is similar to the fluid slurry, and the costs from this are therefore found to be the same.

2.5.2.1.1.2 Issues related to the handling and transportation

The issues that are related to this, are the conditions that are having an effect on the quality of the biomass, the ability to be harvested and the methods needed for handling and transporting the biomasses. It is a known fact that transportation and handling of the biomasses between farmer and biogas plant are having a high influence on the economy in a symbiosis between the two parties (Innovationsnetværket for Biomasse, 2010). The quality of the biomasses is influenced by the weather (Bioenarea, 2011), e.g. is the weather determining the dry matter content in the plant biomasses. A plant biomass that is swathed, can become more expensive to handle, if the biomass gets rain before it is gathered and transported to storage facilities (Bioenarea, 2011). Another problem is that straw material becomes much harder to comminute if the dry matter content is lowered by rain, hereby making the material much harder to handle in the biogas plant (Eggert, 2011).

The driving conditions on the fields and roads will also be affected by the weather conditions, but also by the general conditions on the fields, e.g. low soil with a high water content, or hilly terrain with clay soil that becomes difficult to drive on after rain (Bioenarea, 2011). Therefore, the weather, field and road conditions are determining the equipment that is needed in order to handle and transport the biomasses from field to biogas plant. It is therefore important to select the fields and harvest time, which generates the lowest costs, in order to give the symbiosis possibility for profitability (Bioenarea, 2011).

2.5.2.1.2 Sales options to the produced biogas

This sub-section will investigate two areas. First, the subsidies and sale prices that are related to the sale of the produced energy, the second is determining a method for finding the energy that can be produced from the biogas.

2.5.2.1.2.1 Subsidies and sale prices to the sale options

The possibilities for sale of the produced biogas and/or bi-production of heat will directly influence the location selection for the plant. The sales options in a location will influence the technologies that are needed within the plant, in order to sell the produced biogas or energy at the location, or at a nearby location. Therefore, the technology needed will have influence on the investment needed when purchasing the plant (Deloitte, 2013), but also the earnings generated from selling the biogas. In order to limit the scope of this project it was selected only to look at the sales options for electricity with heart as a bi-product, produced from a gas engine. This is selected, knowing that two other options are available. This is to sell the biogas pure (Deloitte, 2013), or to upgrade the biogas to the natural gas grid.

There are no subsidies related to the production of biogas, but there are subsidies when selling the biogas or converted product to the final customer. When converting biogas into electricity, heat is generated, and is becoming a bi-product to the process. Only a percentage of the biogas is being converted into electricity (Jørgensen P. J., Biogas - Green Energy, 2009) (Innovationsnetværket for Biomasse, 2010), the remaining part is converted into heat or lost in the production. The capacity of the specific gas engine used for converting the biogas, will determine the percentages that are converted (Jørgensen P. J., Biogas - Green Energy, 2009), and will determine the costs of gas engine. A general estimation is 42 percent electricity, 43 percent heat and 15 percent lost in the conversion process (Jørgensen P. J., Biogas - Green Energy, 2009). The fixed sales price for electricity produced from biogas is 0,793 kr. per kWh, with a subsidy of 0,36 kr. per kWh to the seller (Deloitte, 2013). There is no subsidy when selling heat as a bi-product, and the maximal selling price is estimated to be 0,25 kr. per kWh (DLBR, 2008). While the electricity is sold at a fixed price, the selling price of the heat is determined by the selling options in the local community. Therefore, it is noted that the price of 0,25 kr. per kWh is the maximal price that is estimated to be received, in many cases would this be lower or in some cases none.

	Subsidy	Sales price
Electricity	0,36 Kr. per kWh	0,793 Kr. per kWh
Heat as bi-product	None	0,25 kr. per KWh

Table 21 - Prices related to the sale of biogas and energy produced from biogas

2.5.2.1.2.2 Method for determining the energy content

Based on the findings in section 2.5.1.1.1 – *Gas potential in the biomass,* and section 2.5.1.2.2 – *Degradability and methane content*, the production of biogas can be found. The result that can be generated from the findings is an amount of biogas produced per ton biomass, with a certain percentage of methane. The results from the produced biogas need to be converted into energy, which was in sales options to be joule and kWh. The method selected for converting this is the low heating value (LHV) of the biogas (Ludington, 2010). This value indicates how much energy in joules there is per Nm3 biogas, related to the methane content percentage in the biogas. But as found in the sales options, not all subsidies and prices are based on joules, but on kWh produced. 1 kWh is found to be 3,6 MJ (Ludington, 2010). In table 22 – *Energy production per Nm3 biogas based on the methane content,* the amount of energy produced per Nm3 can be found, related to the methane content in the biogas.

Methane percentage %	LHV MJ/Nm3 biogas	kWh/Nm3 biogas
48	17,25	4,79
50	17,96	4,99
52	18,67	5,19
54	19,37	5,38
56	20,12	5,59
58	20,83	5,79
60	21,53	5,98
62	22,28	6,19
64	22,99	6,39
66	23,70	6,58

Table 22 - Energy production per Nm3 biogas based on the methane content (Ludington, 2010)

2.5.2.1.3 Local acceptance of the location

As found in the interviews with the two farmers and from the biogas workshop, acceptance from the local community was found to be an essential factor, when selecting the location of a biogas plant. Therefore, this section will investigate how local acceptance has influence on the location of a biogas plant, and how the local acceptance can be achieved.

Acceptance of renewable energy is achieved through three dimensions (Sovacool & Ratan, 2012);

- Socio-political acceptance
- Market acceptance
- Community acceptance

Due to the fact that market acceptance is set as a precondition to this project the area will not be further investigated in this project. But the fact is that all areas are dependent, in order to achieve the needed acceptance (Soland, Steimer, & Walter, 2013). Biogas plants are, equal to other technical renewable energy plants, such as windmills, treatment plants, waste incinerations etc. (Innovationsnetværket for Biomasse, 2010). Common for all these types of energy plants, is their bad ability to find a build location (Innovationsnetværket for Biomasse, 2010). A factor that is only specific to biogas plants, is the smell perception in the local community (Soland, Steimer, & Walter, 2013), and this factor has to be in counted when selecting a location to a biogas plant. The general public attitude towards renewable energy is positive, but they do not want it to be located in their "backyard", NIMBY (Not In My Backyard) (Hellström, 1998). Their resistance against the biogas plant, can make the process of developing and building the biogas plant difficult, and in worst case kill the projects. However, studies have shown that the involvement of the local community and residents, can change the attitude towards locating a biogas plant in their "backyard", PIMBY (Please In MY Backyard) (Jobert, Laborgne, & Mimler, 2007). Their opposition can be changed through a range of initiatives from the commissioning party, including achieving political support, good communication, presence and local ownership (Innovationsnetværket for Biomasse, 2010).

Political support – A precondition is that there is socio-political support and willingness, towards biogas in the local community (Sovacool & Ratan, 2012). It is a great support if the local municipality has an energy plan that supports biogas, and has location options for future biogas plants in the local plan (Innovationsnetværket for Biomasse, 2010). The municipality will have interest in placing the biogas plant at a location where it will benefit the local residents (Sovacool & Ratan, 2012), hereby enabling sale of the produced biogas to the local residence. Hereby is the political commitment towards the biogas shown, which will have an influence on the local residence attitude towards renewable energy (Sovacool & Ratan, 2012).

Communication and presence – The local citizens and associations, should be parts of the development and decision process, in order to achieve accept of a biogas plant (Innovationsnetværket for Biomasse, 2010). By involving all interested stakeholders in the plant development and location selection, the local community will get a certain ownership over the plant (Soland, Steimer, & Walter, 2013). In relation to the involvement of the local community and the communication towards these, is knowledge sharing. The idea with the biogas project should be presented in different ways, according to which stakeholders that the idea is presented to (Innovationsnetværket for Biomasse, 2010). The idea will quickly spread throughout the local community, so it is highly important to have a communication strategy, determining which knowledge there should be used, towards which stakeholders (Innovationsnetværket for Biomasse, 2010). The important factor is, to get the all stakeholders informed about the basic idea, and environmental impact of the biogas plant, in order to achieve acceptance (Sovacool & Ratan, 2012) (Innovationsnetværket for Biomasse, 2010).

Ownership – It is an option to give the local citizens the opportunity to invest in the biogas plant, hereby giving them ownership, and achieving the acceptance (Warren & McFadyen, 2010) (Soland, Steimer, & Walter, 2013). The investment opportunity will also get the locals involved in the development of the biogas (Soland, Steimer, & Walter, 2013), due to their financial interest in the biogas plant. Another option is to offer them to buy the produced heat at a favorable price (Soland, Steimer, & Walter, 2013), hereby also giving them a financial interest in the plant. The idea by giving them possibility of ownership is to have a more open profile of the project (Innovationsnetværket for Biomasse, 2010).

2.5.2.2 Legal issues

There is a range of legal issues that needed to be considered when developing a biogas plant. The legal issues are related to the approvals that are needed in order to get the building permitted to the plant, and the legal bindings that are needed in the cooperation between the organic farmers and biogas plant. The section has been divided into two sub-sections, the first being about the approvals needed for building the biogas plant, and the second being about the legal bindings that are needed in the symbiosis based on the findings from section 2.1 – *Case study*.

2.5.2.2.1 Getting the building permit

Getting approval of the plant and the wanted location, are processes with certain phases and tasks, which all are defined by the wanted plant and the selected location. In figure 17 – *Process for getting a building permit,* the process of getting a building permit can be seen. Under the figure the phases and task will be described.

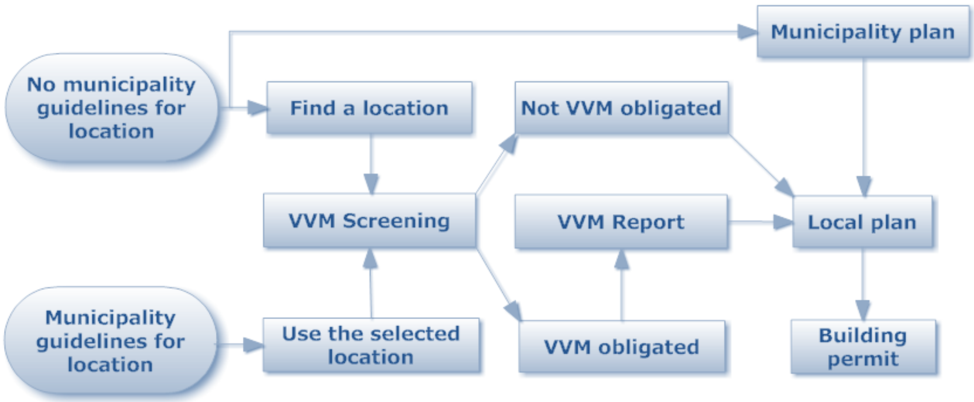


Figure 17 - Process for getting a building permit

The first step is to investigate whether the municipality has a local plan over options for locating biogas plants, every municipality should have this based on the green growth agreement (The Danish Goverment, 2009). If this is not the case, the commissioning party needs to find a location and start a process of getting a municipality plan over location of the biogas plant (Innovationsnetværket for Biomasse, 2010). This is also needed if the biogas plant is placed outside the suggested area in the district plan. All biogas plants are obligated to be VVM screened in order to evaluate the environmental impact from the plant (Miljøministeriet Naturstyrelsen, 2014). The local municipality will here after determine if the biogas project is obligated to make a VVM report, or if the projects are developed according to an existing frame within the local plan. If the biogas plant does not need to make VVM report, or when the VVM report is approved, the biogas project is in compliance with the local plan (Innovationsnetværket for Biomasse, 2010).

In order to get the building permit the biogas plants need an environmental approval, this allowing the plant to be used for production. The environmental approval is based on a standard term (Miljøministeriet - Miljøstyrelsen, 2008), developed from Miljøministriet. The last task that is needed in order to have the full building permit, is to make a building notification to the municipality (Innovationsnetværket for Biomasse, 2010), hereby getting the final building approval. All these approvals are highly time-consuming, and the advice is to run the applications for approval simultaneously (Innovationsnetværket for Biomasse, 2010).

2.5.2.2.2 Bindings in the symbiosis

As found in the case study there is a need for legal binding in-between the organic farmers and a biogas plant in a symbiosis. The legal bindings are needed due to the great dependence the two parties have on each other, and the products, processed by the third other party. The normal procedure is to make a contract between the two parties (Innovationsnetværket for Biomasse, 2010), and hereby obligating them to deliver biomass to the other party in the cooperation.

2.5.3 Summary and interim conclusion

This sub-section will contain a summary of the findings from the literature review. Also will an interim conclusion to the literature review be presented, in order to conclude on the findings from this section.

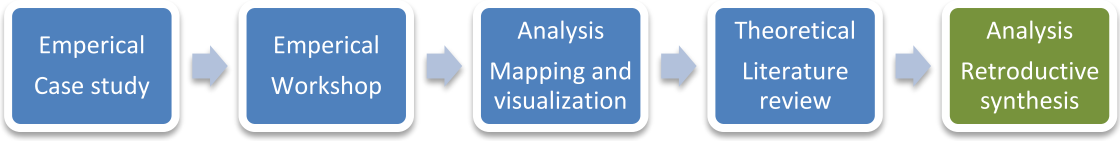
The Symbiosis			
Actor	**Factors**	**Area**	**Description**
The organic farmers	Crop rotation and the relation to gas and fertilizer potential	Biomass in the crop rotation	The essential parameter for the crop rotation in organic have been found, hereunder, crop selection, weed control, collecting nutrients and focus on generating earnings.
		Gas potential in the biomasses	A method for determining the gas potential in biomasses, based on the content of substances (Protein, fat and carbohydrates) in the dry matter has been identified. The content of substances can be found in the NorFor feed table.
		Fertilizer potential in the degasified biomass	The fertilizing potential in the crop biomasses in the Sjællandcase has been found in the NorFor feed table.
	Degasified biomass as fertilizer will determine the possible earnings for the farmers	Fertilizing ability in the biomass	Through the investigations it was found the fertilizing abilities of the degasified biomass are determined by the content of NH4-N.
		Crops ability to use the fertilizer given	It is found that the three main nutrients for crops are nitrogen, phosphorus and potassium. Nitrogen has immediate effect on the crop, while the others have effect over a longer time period.
		Extra yield in the crop rotation	The extra yield and earnings a crop can generate will determine the plan for supplying fertilizer. The yield response to fertilizer has been found based on earlier work from VFL.
The biogas plant	The biomass for the biogas plant will determine the biogas plant	Technical difficulties with the biomass	The biomasses and the specific plant will determine the handling and treatment that is needed, hereunder comminution, to increase the surface

	needed		area and to make it pumpable, and pretreatment before the process. The method selected will be in relation to the earnings that can be generated.
		Limitations in the process	It is found that the limitations in the process are related to the inhibition of the process. The limitations are determined by the biomasses selected, due to the physical and inhibition factors in these. The factor found most important for this project is the content of nitrogen in the biomass.
	The biomass and the technical solutions used will determine the output	Output of gas	A method for determining the output of biogas has been found based on the degradability and methane content in the substances (Protein, fat and carbohydrates).
		Output of fertilizer	It is found that approximately 50 percent of the organic nitrogen will be converted into NH4-N, during the degasification of the biomasses.
The symbiosis	Determination of the location of the plant	Transportation and handling of the biomasses	The cost of harvesting, loading, transporting and storage of the biomasses have been found. Also has the issues related to this area been identified. The most important issue is the loss of nutrient content during the transportation and handling.
		Sales options for the energy produced	The sale from the biogas plant is electricity and heat. The sale price and subsidies in relation to the sale of electricity and heat have been found.
		Local acceptance	Three areas have been identified in order to get acceptance in the local community. The factors are political support, communications and presence, and ownership within the local community.
	Legal issues	Acquiring the building permit	The process of acquiring the permit is related to the location of the plant, and the municipality plan. These factors will determine if a VVM approval is needed before the building permit can be given, in relation to the local plan.
		Legal bindings in the symbiosis	The standard legal bindings in the relationship between farmers and biogas plant, will be able to handle the legal bindings needed in the symbiosis.

2.5.3.1 Interim conclusion

Knowledge has been generated in relation to the areas identified in the three previous sections, in the research method. Knowledge has been gathered in order to be able to calculate the output of biogas and fertilizer from the biogas plant, and the output of extra yield from the farmers. The earnings that can be generated from the productions at the two parties have also been found, in order to determine the earnings from each of the two parties. Also has the cost related to the production at the two parties been determined, this was done in order to be able of calculate the profit for each of the two parties in the symbiosis. The cost related to the transportation and handling in the symbiosis has also been found, in order to be able to calculate the cost in the symbiosis. The findings in the literature review will now be analyzed and verified in the retroductive synthesis, in order to make them useable for the business case.

2.6 RETRODUCTIVE SYNTHESIS



This section will analyze and verify the main findings that are made in the literature review, this in order to use the knowledge in the business case. The theoretical output of biogas and fertilizer from the biogas plant, and output of crops from the farmers, will be calculated for each of the crops in the Sjællandcase. The result from the theoretical calculations of biogas output will be verified by comparing the calculated values, with measured values of a similar biomass. The limitations in the biomasses from the Sjællandcase will be found, in order to use this knowledge in the Sjællandcase.

2.6.1 Theoretical output from the biogas process

The findings in the literature study will in the section be used in order to calculate the output from each of the biomasses in the biogas process. The theoretical output of biogas and fertilizer will be found for each of the biomasses. The calculated output of biogas from the biomasses will be compared with trails made on similar biomasses, in order to validate the results of the theoretical calculations. The theoretical output will also be used in order to compare and validate the plant offers collected in the business case.

2.6.1.1 Output of biogas

From the findings in section 2.5.1.1.1 – *Gas potential in the biomass* and section 2.5.1.2.2 – *Degradability and methane content*, the output of biogas from the biogas process is found for each of the biomasses, in a mesophilic and thermophilic process. In appendix 10 – *Calculation of biogas output,* the Excel sheet with the calculations can be found. In table 23 – *Comparison of the theoretical and measured methane production mesophilic,* and table 24 – *Comparison of the theoretical and measured methane production thermophilic*, the theoretical output measured output of methane from the biomasses in the Sjællandcase can be seen.

Biomass (Mesophilic)	Theoretical production	Measured production	Deviation
Unit	CH4 Nm3/ton Total	CH4 Nm3/ton Total	%
Clover grass silage	107,2	120,05	10,70
Straw + clover grass silage	123,83	115,48	-7,23
Seed grass straw	191,67	-	-
Straw	204,42	146,12	-38,90

Permanent grass silage	103,01	103,74	0,70
Carrots + tops	37,46	60,69	38,27
Regrown seed grass silage	82,88	114,54	27,64
Separated grains	203,01	228,84	11,29
Yellow mustard silage	30,14	41,57	27,51
Average	**-**	**-**	**8,62**

Table 23 - Comparison of the theoretical and measured methane production mesophilic

Biomass (Thermophilic)	Theoretical production	Measured production	Deviation
Unit	CH4 Nm3/ton Total	CH4 Nm3/ton Total	%
Clover grass silage	121,17	120,05	-0,93
Straw + clover grass silage	141,17	115,48	-22,25
Seed grass straw	216,41	-	-
Straw	230,47	146,12	-57,73
Permanent grass silage	117,36	103,74	-13,13
Carrots + tops	44,52	60,69	26,64
Regrown seed grass silage	93,08	114,54	18,73
Separated grains	257,98	228,84	-12,73
Yellow mustard silage	37,53	41,57	9,73
Average	**-**	**-**	**-6,83**

Table 24 - Comparison of the theoretical and measured methane production thermophilic

As seen in the two tables there is a degree of deviation between the theoretical and measured production. The difference in the results can be due to a range of different reasons. The methods and, the exact content of the biomasses, are in the measured productions unknown, which makes it difficult to determine what is resulting in the deviation. The deviation of the amount of output from straw and separated grains is found to be due to the content of lignin in these biomasses, which in a practical trail will not be degraded, unless it has been pretreated. The fact that the content of the substances in the practical trails is unknown, could have a massive impact on the deviations that are found between the theoretical and measured biogas production from the biomasses. In addition, the degradability of the substances in the theoretical calculations is simplified, which could result in a different outcome than what is found in the measured trails.

Based on the found output of methane, the output of biogas can be found to be the calculated methane content in the biogas produced from a biomass. The biogas produced from the biomasses can be found in table 25 – *Theoretical methane content and biogas production mesophilic,* and table 26 – *Theoretical methane content and biogas production mesophilic*.

Biomass (Mesophilic)	Methane content	Biogas production
Unit	%	Nm3/ton Total
Clover grass silage	53,96	198,66
Straw + clover grass silage	52,71	234,95
Seed grass straw	51,71	370,69
Straw	51,42	397,56
Permanent grass silage	53,75	191,63
Carrots + tops	52,31	71,63
Regrown seed grass silage	54,69	151,55
Separated grains	53,17	381,84
Yellow mustard silage	50,00	60,27

Table 25 - Theoretical methane content and biogas production mesophilic

Biomass (Thermophilic)	Methane content	Biogas production
Unit	%	Nm3/ton Total
Clover grass silage	53,92	203,37
Straw + clover grass silage	52,65	261,17
Seed grass straw	51,72	394,55
Straw	51,39	428,28
Permanent grass silage	53,68	197,22
Carrots + tops	52,21	70,00
Regrown seed grass silage	54,66	150,37
Separated grains	52,77	478,63
Yellow mustard silage	50,00	64,94

Table 26 - Theoretical methane content and biogas production thermophilic

As seen in the two tables the content of methane is highly similar when using mesophilic and thermophilic fermentation, which is found to be true due to the fact that the same content is degraded during the two processes, but with a different degradability. The different degradability is seen by the larger amount of biogas that is produced using the thermophilic fermentation. It is seen that the output of biogas using thermophilic fermentation is lower for carrots and regrown seed grass silage, which is found to be an error in the theoretical calculations. It is found in the literature that the degradability of sugar is lower using thermophilic than mesophilic fermentation, which is found to be untrue, due to the fact that the bacteria are working faster in a thermophilic environment, hereby having a better degradability of the substances in the process. This could be one of the reasons to the biogas production from the two biomasses being lower in thermophilic fermentation.

2.6.1.2 Output of fertilizer

From the findings in section 2.5.1.1.2 – *Fertilizer potential in the degasified biomass,* and section 2.5.1.1.2 – *Fertilizer potential in the degasified biomass*, the fertilizer output from the biomasses, after being degasified, can be found. Because no content of fertilizer is expected to disappear during the degasification, the amount of fertilizer in the remaining fraction will be the same, but the content of fertilizer nutrients will be higher, making it a better fertilizer. In addition, 50 percent of the organic nitrogen is converted into organic nitrogen, which will make the fertilizing ability of the degasified biomass much better than the input material. Torkild Birkmose[22], Peter Mejnertsen and Holger Schulz[23] have verified the conversion of 50 percent nitrogen during a biogas process. In addition, Peter Mejnertsen has stated that the transformation of P and K during the degasification is not found important, due to the fact that the effect of these nutrients, on the crop yield, are hard to register over a short period of time like a year. Therefore, only the immediate effect from the nitrogen is found important. In table 27 – *Theoretical fertilizer content in the degasified biomasses mesophilic,* and table 28 - *Theoretical fertilizer content in the degasified biomasses thermophilic,* the content of fertilizer in the degasified biomasses can be found.

[22] Conversation with Torkild Birkmose and Peter Mejnertsen at VFL – Appendix 4 – Interviews/conversations

[23] Appendix 11 – Interview with Agrikomp

Biomass (Mesophilic)	Fraction	Total-N	NH4-N	Org-N	NH4-N
Unit	Kg/ton FM	Kg/ton	Kg/ton	Kg/ton	%
Clover grass silage	737,51	13,40	7,06	6,34	52,6
Straw + clover grass silage	713,28	11,30	5,87	5,43	51,9
Seed grass straw	612,09	14,89	7,44	7,44	50,0
Straw	605,62	8,89	4,49	4,49	50,0
Permanent grass silage	748,00	12,06	6,49	5,57	53,8
Carrots + tops	893,99	3,92	2,77	1,15	70,6
Regrown seed grass silage	751,18	11,97	6,38	5,59	53,2
Separated grains	534,72	15,90	9,35	6,55	58,8
Yellow mustard silage	917,85	4,42	2,21	2,21	50,0

Table 27 - Theoretical fertilizer content in the degasified biomasses mesophilic

Biomass (Thermophilic)	Fraction	Total-N	NH4-N	Org-N	NH4-N
Unit	Kg/ton FM	Kg/ton	Kg/ton	Kg/ton	%
Clover grass silage	701,63	14,09	7,42	6,66	52,6
Straw + clover grass silage	671,62	12,00	6,24	5,77	52,0
Seed grass straw	572,21	15,92	7,96	7,96	50,0
Straw	564,98	9,63	4,81	4,81	50,0
Permanent grass silage	710,94	12,69	6,83	5,86	53,8
Carrots + tops	873,75	4,01	2,83	1,17	70,6
Regrown seed grass silage	718,46	12,52	6,67	5,85	53,3
Separated grains	400,93	21,20	12,47	8,73	58,8
Yellow mustard silage	897,70	4,52	2,26	2,26	50,0

Table 28 - Theoretical fertilizer content in the degasified biomasses thermophilic

As seen in the two tables the content of fertilizer increases, when using thermophilic fermentation. This is due to the higher degradability, which increases the content of fertilizing nutrients in the remaining fraction. The higher degradability can be seen in section 2.5.1.2.2 – *Degradability and methane content*. The percentage of ammonium nitrogen of the total amount of nitrogen has also been found, due to this being the fraction creating a yield in the crops. There is also found to be fertilizing ability in the organic nitrogen, but this is highly limited, due to the low knowledge of the degradation level in the soil. Peter Mejnertsen states that the effect from the organic nitrogen will be very low, and very hard to define, so this effect should not be a part of the calculation, when determining the yield response from fertilizing with the degasified biomass.

2.6.2 Total output from the biomasses

Now that both outputs from the biogas production have been found, the total output of the degasification of the biomasses can be found. The total output of the biogas process, is the output of methane, biogas and NH4-N, due to these being the elements that are generating income. The total output from the process can be found in table 29 – *Total output from mesophilic digestion,* and table 30 - *Total output from thermophilic digestion*.

Biomass (Mesophilic)	Methane	Biogas	NH4-N
Unit	CH4 Nm3/ton	Nm3/ton	Kg/ton
Clover grass silage	107,2	198,66	7,06
Straw + clover grass silage	123,83	234,95	5,87
Seed grass straw	191,67	370,69	7,44

Straw	204,42	397,56	4,49
Permanent grass silage	103,01	191,63	6,49
Carrots + tops	37,46	71,63	2,77
Regrown seed grass silage	82,88	151,55	6,38
Separated grains	203,01	381,84	9,35
Yellow mustard silage	30,14	60,27	2,21

Table 29 - Total output from mesophilic digestion

Biomass (Thermophilic)	Methane	Biogas	NH4-N
Unit	CH4 Nm3/ton	Nm3/ton	Kg/ton
Clover grass silage	121,17	203,37	7,42
Straw + clover grass silage	141,17	261,17	6,24
Seed grass straw	216,41	394,55	7,96
Straw	230,47	428,28	4,81
Permanent grass silage	117,36	197,22	6,83
Carrots + tops	44,52	70,00	2,83
Regrown seed grass silage	93,08	150,37	6,67
Separated grains	257,98	478,63	12,47
Yellow mustard silage	37,53	64,94	2,26

Table 30 - Total output from thermophilic digestion

2.6.3 Limitations from the biomasses

Based on the findings in section 2.5.1.2.1 – *Limiting factors in the biogas process* the limitations the biomasses can give to the production of biogas can be found. It was found that the content of NH4-N would be inhibiting when the level was between 1 – 6 kg/ton. All the degasified biomasses have a content that is in this range, or even has a content that is higher, which will be toxic to the process. Therefore, the content of NH4-N is found to be inhibiting the production of biogas. However, it was found in the literature review that each biogas plant has a different inhabitation level, and different plants could therefore be able to handle the content of NH4-N. Another issue that is limited by the biomasses is the dry matter content in the biomasses. For the plants where the biomasses should be pumped, the dry matter content in straws and separated grain is too high. Therefore, a plant where the biomasses should be pumpeable will only be able of taking a percentage of the biomasses with high dry matter content. If a plant can handle a dry matter content of maximal 40 percent, adding 1 kg of straw would need 24 kg of clover grass in order to get the content below 40 percent. Due to the great amount of straw in the Sjællandcase it is important to know the maximal level of dry matter content the plants is able of processing, in order to find the best composition of the biomasses, hereby making the symbiosis as profitable as possible.

2.6.4 Plant offers from manufactures

As mentioned in the introduction most plants are based on slurry as the main biomass, and most plants are therefore using technology that relies on slurry being the main biomass in order for the plant to function. The object of this project is to find plants and technologies that can handle, and degasify, solid biomasses from crop material, and hereby generate profit for both farmers and biogas plant in the symbiosis. In order to find the costs of a plant and the technologies that are needed, a range of manufactures[24] were asked to make an offer for a plant that are running on the organic biomasses from the Sjællandcase.

[24] Appendix 12 - List of manufactures

As found in section 2.6.3 – *Limitations from the biomasses* the maximal content of NH4-N and dry matter is needed to be known in order to determine the best composition of the biomasses. Therefore, the plant manufactures were asked to make a plant offer that could handle the biomasses in the case, hereby getting the knowledge of the maximal content of NH4-N and dry matter, which their plant solution can handle. They will also need to calculate the output from the plant, hereby giving an understanding of their theoretical biogas and fertilizer output. The last object was to get an overview on the investment and operation costs of the different plants, in order to find profitability in the symbiosis. In order to get these needed answers from the manufactures, material on the Sjællandcase was send to the manufactures.

The material, which the manufactures received, can be seen in appendix 13 – *Material to the plant manufactures*. The answers will give a view on the different approaches available to handle the biomasses, and the costs that are related to a plant that can handle the biomasses in the Sjællandcase. These answers will later on be used in the business case, in order to find the plant that is most suitable for the case. The plant offers received can be seen in appendix 14 – *Plant offers received*.

2.6.5 Distribution keys in the symbiosis

Due to the fact that the economy for the two parties in the symbiosis, will be seen as one throughout the calculations in the business case, there is a need for distributions keys that divides the costs and profit between the two parties. A distribution key is needed in order to distribute the degasified biomass from the plant offers. This will enable the researcher to calculate the earnings generated by each of the farmers, by using the degasified biomass as fertilizer. Also is a distribution key needed, in order to divide the costs and profits generated in the symbiosis, between the two parties.

2.6.5.1 Distribution of the produced fertilizer

Due to the fact that the degasified biomass needs to be divided into the three farmers in a fair manner, there is a need for a distribution key. Therefore this issue was discussed with Peter Mejnertsen[25], hereby finding methods to determine the amount of degasified biomass the farmers should receive, after the biogas production. The reason why this is needed is that the farmers deliver different amounts of biomass to the case, and that the amount of fertilizer received will have a massive impact on the profit they are capable of generating. Two methods were found to be interesting for the case. The first method is to distribute the degasified biomass back to the farmers based on the amount of biomass they have delivered to the plant. Hereby dividing the degasified based on the percentage the farmers have delivered to the plant. The second method that was identified is to distribute the degasified biomass back to the farmers, based on the amount of fertilizer they have delivered to the plant. Hereby the farmers will benefit from getting a great amount of fertilizer in return, if they are able of delivering a high amount of biomasses with high fertilizer content. The second method will ensure that the farmers get the same amount of fertilizer in return as they have delivered to the plant, while the first method cannot ensure that the amount of fertilizer getting in return is higher or lower than the amount delivered to the plant.

The two methods found will be tested in the business case in order to analyze which of the two methods is most suitable to use in the Sjællandcase.

[25] Conversation with Peter Mejnertsen at VFL – Appendix 4 – Interviews/conversations

2.6.5.2 *Distribution of costs and profits in the symbiosis*

Based on the fact that both parties are generating a profit from the symbiosis, and the fact that there are costs related to the symbiosis, a distribution key of these two factors is needed. When looking on the profits generated by the two parties, the investor in the biogas plant is already secured 10 percent annual return of investment. The farmers are mean while not secured any profit, but the farmers risk in the symbiosis is also found to be minimal compared to the investors. But after receiving the 10 percent in annual return of investment, is the risk also found to be low for the investor. Therefore, is the optimal distribution key found to be by dividing the costs and profits based the generated profit. The costs and profits will be divided based on the percentage of the total profit, each of the two parties have generated.

This method of dividing the costs and profits will be tested in the business case, in order to evaluate whether this is a suitable distribution key.

2.6.6 Interim conclusion

Now where the main areas for the business case have been addressed, the business case can be conducted. The section has provided knowledge on the output of biogas and fertilizer from each of the biomasses in the Sjællandcase. This will be used in order to find the amount of degasified biomass, and hereby fertilizer, from each of the plant offer received. This will be used in order to calculate the earnings that can be generated from the farmers in the symbiosis. The output of biogas found in this section, will be used in order to validate the output stated from the manufactures in the plant offers. Material from the Sjællandcase was developed in order to get plant offers from manufactures, which can be used in the calculations of the profitability in the symbiosis. Also has distribution keys been developed for the symbiosis, in order to be able to distribute the costs and profits generated.

2.7 CONCLUSION TO RESEARCH METHOD

This section will conclude on the research method phase. This will be conducted through a presentation of the process flow that is found in symbiosis. This process flow will be used in the following business case, in order to calculate the profitability. Following will a conclusion highlight the main findings of the research method phase.

2.7.1 Process flow in the symbiosis

In Section 2.4.1.1 – *The symbiosis,* the interaction between the farmers and biogas plant was found, this in order to find relevant literature to the symbiosis. Based on the illustration and description from that section, and the newfound knowledge in the literature review, a more specific process is developed.

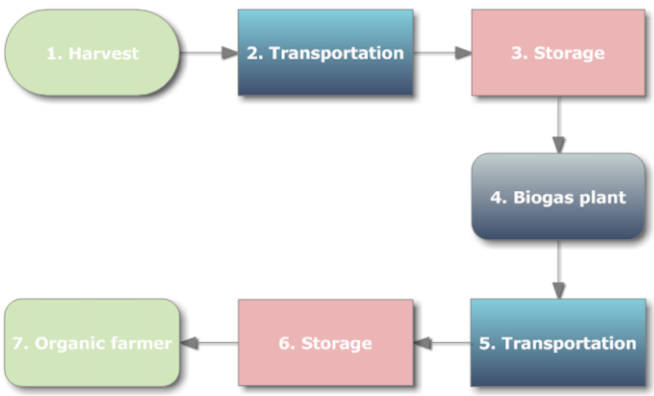


Figure 18 - Process flow in the symbiosis

1. **Harvesting of the biomasses** – The biomasses are harvested and gathered on the fields of the farmers.

2. **Transportation of the biomasses** – The harvested biomasses are loaded on to trucks and transported to the biogas plant.

3. **Storage of the biomasses** – The biomasses are unloaded and storage at the biogas plant, in a matter that preserves the quality of the biomasses.

4. **Utilization of the biogas potential** – The biogas potential is utilized in the biogas plants over the following year.

5. **Transportation of the degasified biomasses** – After the biogas potential has been utilized the degasified biomass is transported back to the farmers.

6. **Storage of the degasified biomasses** – The degasified biomass is storage at the farmers, in a matter that preserve the quality of the degasified biomass.

7. **Utilization of the fertilizing potential** – The fertilizing potential in the degasified biomass is utilized by being spread on to the fields of the farmers, hereby generating extra yield.

Step 1,2,3,5 and 6 is related to the joint costs there are in the symbiosis, while step 4 is the process related to the operation on the biogas plant converting the biomasses to biogas, hereby generating earnings to the biogas plant. Step 7 is the process related to the farmer utilizing the fertilizer potential in the degasified biomass, hereby generating earnings to the farmer. Therefore, the process is found to be consisting of three areas; biogas utilization at the plant, fertilizer utilization at the farmers and the handling and distribution in the symbiosis. In the following sections these three areas will be used in order to find the costs and earnings related to the process steps.

2.7.2 Conclusion

The research method has been used, in order to investigate the problem statement through empirical and theoretical studies. The studies have enabled the researcher in calculating the profitability in the symbiosis, based on the Sjællandcase. The case study on the Sjællandcase has resulted in goals for the business case, which are stating the framework in the business case. The workshop identified important areas in the symbiosis and synergy, which is used in the order to define the two areas. Furthermore has the workshop identified barriers, in the symbiosis and synergy. This knowledge will be used to discuss the symbiosis and synergy in the discussion. The findings in the case study and workshop enabled a visualization and mapping of the symbiosis and synergy, and a definition of the two areas. This definition is used throughout the remaining project, when addressing these two areas. The literature review found the needed knowledge, in order to solve the areas found in the empirical studies. This has created the needed knowledge in order to solve the goals for the business case, as they were found in the case study. The retroductive synthesis used the main findings from the literature study, in order to make the knowledge useable for the business case. The retroductive synthesis developed material for the plant offers that are needed in order to calculate the profitability in the symbiosis. The research method phases have gathered the needed knowledge in order to calculate the profitability in the symbiosis in the Sjællandcase, and in order to discuss the symbiosis and the synergy in the discussion.

3. BUSINESS CASE

The business case will be addressed as found in the proposed approach from VFL in section 2.4.3 – *VFLs approach to biogas projects*. Therefor will the business case be based upon the three steps for the business case, as can be seen in figure 19 – *Steps in the business case*.

Figure 19 - Steps in the business case

3.1 FRAMEWORK FOR THE BUSINESS CASE

In order to make a business case based on the Sjællandcase, a framework needs to be made. This specific location for the biogas plant in the Sjællandcase is found. This is done in cooperation with Peter Mejnertsen[26], whom is one of the farmers in the case study. The selected location can be seen in figure 20 – *Location of the biogas plant in the Sjællandcase*.

Figure 20 - Location of the biogas plant in the Sjællandcase

The location is selected due to the good infrastructure, which is found to give the optimal conditions for the symbiosis. The locations are in an equal distance from each of the farmers in the case. As described in the case study, it is a precondition to the case that an investor for the biogas plant is found. The precondition states that an investor is expected to have a minimum of 10 percent annual return of investment, in the biogas plant. Therefor is the annual return of investment for the investor an annual cost for the biogas plant. This is in the case set at 10 percent, whereas the possible excess from the symbiosis will increase the return of investment for the investor. The live time of the biogas plant, and the machinery used on the biogas plant, is set at 15 years. This states that the depreciation of the investments will be at 6,66 percent each year. The value of the plant will therefore be none of the expected lifetime of 15 years. The amount of biomasses the plant manufactures are using in their offers is in some cases more than the available amount form the Sjællandcase. Allowing the plant manufactures to deviate from the amounts in the Sjællandcase, is a choice from VFL, hereby giving the manufactures the opportunity to present the optimal biomass composition for their specific plant. The amount of biomass is multiplied in order to

[26] Conversation with Peter Mejnertsen at VFL – Appendix 4 – Interviews/conversations

find the appropriate amount, and this is also the case for the amount of biomass from each farmer. The plant offers have been presented for Peter Mejnertsen, where from hi has verified that the amount of biomass needed in each offer could be found in the three farmer's crop rotation. Therefore, the business case is calculated based on the amount of biomass stated in each of the plant offers, while the farmers are still expected to have the same composition of biomasses.

The business case in calculated from a best case scenario. Using this approach to calculate the business case will help identify the maximal profitability in the symbiosis. The best case scenario implicates that all sellable heat can be sold at the optimal price, and that no fertilizer ability is lost in the transportation and handling of the biomasses. Also is the scenario calculated based on the degasified biomass being the only fertilizer available for the farmers. This is selected due to the fact that the objective in this project is to make more available for the farmers.

3.2 TECHNICAL PLANT SOLUTIONS

This section will describe the process that is found to be in the symbiosis, between farmers and biogas plant in the Sjællandcase. This will also help illustrate the areas that are relevant for the business case. This section will analyze the technical solutions that are received from the manufactures in their plant offers, this in order to give an indication of the capabilities in the different offers.

As described in section 2.6.5 – *Plant offers from manufactures,* a range of companies have given offers to a suitable plant in the Sjællandcase. All plant offers can be found in appendix 14 – *Plant offers received*. The technical solutions in the plants offers can be divided into three groups; Slurry based wet fermentation plants, Non-slurry based wet fermentation plants and garage dry fermentation plants. In table 31 – *Technical solution in the plant offers* the technical solutions from the received offers can be found. The solutions in the offers will be further described below the table.

Plant	Dranco	Sauter	Agrikomp	Combigas	Aikan
Type	Slurry	Non-slurry	Non-slurry	Slurry	Garage
Temperature	Mesophilic	Mesophilic	Mesophilic	Thermophilic	Thermophilic
Max Dry matter content	25 %	40 %	40 %	15 %	None

Table 31 - Technical solution in the plant offers

The Slurry based plants are the most common plants, where slurry is needed in extensive amounts in order to make the biomass in the plant pumpable. The use of slurry will limit the dry matter content in the biomass that is processed in the plant. The object of the project is also to find a plant that can handle a great amount of biomass from crop material where the dry matter are high, therefore these plants are not fully interesting in the context of the object of the project. However, due to the amount of conventional slurry that is available in the case, the plants are still analyzed further, hereby knowing that these plants might not get organic status, which will imply that the fertilizer will not be organic. This fact will question whether the slurry based plants can handle the problem of acquiring more organic fertilizer to the organic farmers.

The non-slurry based plants are stated to be able to handle maximal dry matter content between 40 – 50 percent. This makes these plants capable of handling the biomasses in the case, and run the plant on biomasses that are only organic, hereby getting status of fully organic. In order to make the biomass be processed pumpable, a separator is used in all the solutions. The separator will separate fluid from the biomass, and reuse this fraction in the process, hereby making the biomass pumpable with a high content of dry matter.

The garage based plants are also able of handling a high content of biomass this due to the biomass being degasified is not moved during the process. The biomasses are stationary in the garage during the process, while only the percolate is pumped between the garage and the reactor tank. This enables the plant of handling biomasses, without a limitation in the dry matter content.

3.3 INVESTMENT NEEDED

The different companies have provided a price that is needed when investing in their plant. This section will state the investment that is needed in order to buy, build and make the plants operational. In table 32 – *Investment needed in the plant offers* the investment needed in the plants can be found. The plant offers are related to the biomass composition that has been selected from the manufactures, based on the material developed from VFL.

Plant	**Dranco**	**Sauter**	**Agrikomp**	**Combigas**	**Aikan**
Plant	44.946.500 kr.	10.875.168 kr.	16.785.000 kr.	15.976.940 kr.	58.188.000 kr.
Machinery	1.119.000 kr.*	1.454.700 kr.	1.119.000 kr.	1.119.000 kr.*	6.341.000 kr.
Land	100.000 kr.	100.000 kr.	100.000 kr.	100.000 kr.	100.000 kr.
Total investment	**45.046.501 kr.**	**12.429.869 kr.**	**18.004.001 kr.**	**17.195.941 kr.**	**64.629.001 kr.**
Ton FM	40.630	10.400	12.535	47.715	20.500
Ton DM	10.813	3.386	4.712	6.614	7.507
Investment pr. ton FM input	1108 kr.	1.195 kr.	1.436 kr.	360 kr.	3.152 kr.
Investment pr. ton DM input	4166 kr.	3.671 kr.	3.821 kr.	2.600 kr.	8609 kr.

Table 32 - Investment needed in the plant offers

As it can be seen in table 32 – *Investment needed in the plant offers* the different technical solutions has different investment needs. One of the reasons the investment needs differ between the biogas plants, is that the plants handle different amount of biomass. Therefore, the investment is found in relation to the input material the specific plant is using. The investment is found to be cheapest for the slurry based plants. The non-slurry based plants are found to be three times as expensive per ton dry matter the plant needs to handle, as the slurry based plant from Combigas. The garage based plant is found to be much more expensive than the two other plant types.

3.4 COSTS IN THE SYMBIOSIS

The costs that are related to the plants are found in relation to the three areas found in the process flow in the symbiosis. The costs related to the three areas are found for each year.

3.4.1 Cost related to the plants

The costs in this sub-section are the annual cost related to the plant offers. The annual cost is divided on to two areas, the operation costs and other annual costs. The operational cost are related to the cost of operating and maintaining the biogas plant, hereunder maintenance of the plant and engine, machinery, labor and insurance. Other annual cost is the return of investment for the investor, and the deprecation of the biogas plant. In table 33 – *Annual costs related to the plant offers,* the costs related to the plant offers can be found.

Plant	Dranco	Sauter	Agrikomp	Combigas	Aikan
Maintenance of the plant	2.247.325 kr.*	546.181 kr.	223.800 kr.	74.600 kr.	2.909.400 kr.*
Maintenance of gas engine	495.425 kr.*	184.390 kr.*	207.420 kr.	332.724 kr.*	158.137 kr.*
Machinery cost	193.147 kr.*	193.147 kr.	100.411 kr.	110.453 kr.*	321.317 kr.
Labor cost (200 kr./h)	387.441 kr.*	387.441 kr.	201.420 kr.	221.561 kr.	644.544 kr.
Insurance (1 % of investment)	449.465 kr.	108.752 kr.	167.850 kr.	159.769 kr.	581.880 kr.
Annual operation costs	**3.772.803 kr.**	**1.419.911 kr.**	**900.901 kr.**	**899.524 kr.**	**4.615.967 kr.**
Return of investment	4.504.650 kr.	1.242.987 kr.	1.800.400 kr.	1.719.594 kr.	6.462.900 kr.
Deprecation	2.996.433 kr.	821.991 kr.	1.193.600 kr.	1.139.729 kr.	4.301.933 kr.
Total annual cost	**11.273.887 kr.**	**3.484.889 kr.**	**3.894.901 kr.**	**3.758.431 kr.**	**15.380.800 kr.**
Cost pr. ton FM input	277,47 kr.	335,08 kr.	310,72 kr.	78,76 kr.	750,28 kr.
Cost pr. ton DM input	1042,62 kr.	1029,20 kr.	826,59 kr.	568,25 kr.	2048,86 kr.

Table 33 – Annual costs related to the plant offers - *Estimated

As with the investment needed in the plant, the cost for operating and maintaining the biogas plants differs in relation to the technical solutions. Also in this area are slurry based plant from Combigas the least expensive, and the garage plants as the most expensive.

3.4.2 Cost related to the farmers

The costs related to the farmers, are the spreading of the degasified biomass as fertilizer. In order to know the costs for each of the farmers, a method for determining the distribution of degasified biomass to the farmers in the symbiosis is needed. In section 2.6.5.1 – *Distribution of the produced fertilizer* two methods were found in order to distribute the degasified biomass back to the farmers. Both methods are tested in relation to the distribution of the degasified biomass from the plants[27]. The result of the test was that the distribution based on the two methods was similar, which was due to the fact that the farmers have a similar biomass composition, and therefore is the amount of nitrogen delivered to the biogas plant also similar. Therefore, it is selected to use the method based on the amount of biomass that are delivered to the plant, due to this method being simpler to use. In table 34 – *Annual cost for the farmers,* the distribution of the degasified biomass can be found, and the costs each farmer has for spreading the degasified biomass as fertilizer.

Plant	Dranco	Sauter	Agrikomp	Combigas	Aikan
Degasified biomass ton	35.042	8.275	10.297	44.671	6.500
Christian Jørgensen ton	8.893	2.393	1.406	13.052	1.210
Cost of spreading	311.266 kr.	76.990 kr.	47.252 kr.	326.326 kr.	42.339 kr.
Niels Mejnertsen ton	10.532	1.916	3.551	15.109	1.369
Cost of spreading	368.612 kr.	61.630 kr.	119.307 kr.	377.728 kr.	47.909 kr.
Peter Mejnertsen ton	15.617	3.966	5.340	16.509	3.921
Cost of spreading	546.592 kr.	127.625 kr.	179.416 kr.	412.721 kr.	137.251 kr.
Total cost for the farmers	**1.226.470 kr.**	**266.245 kr.**	**345.975 kr.**	**1.116.775 kr.**	**227.500 kr.**
Cost per ton degasified biomass	35 kr.	32,17 kr.	33,59 kr.	25 kr.	35 kr.

Table 34 – Annual cost for the farmers

3.4.3 Cost related to the symbiosis

The costs related to the symbiosis, are the costs for harvesting, loading, transporting and storing of the biomass, as it is found in the process flow for the symbiosis.

Therefore, the costs in the symbiosis are found in relation to the amount of biomass and degasified biomass the farmers have in the symbiosis. In table 36 – *Annual cost for delivering the biomasses to the biogas plant,* the annual cost for delivering the biomasses to the biogas plant can be found, while the annual cost for distributing the degasified biomass back to the farmers can be found in table 37 - *Annual cost for delivering the degasified biomasses to the*

[27] Appendix 15 – *Distribution key to the degasified biomass*

farmers. The calculation of the costs in the symbiosis is made based on the selected location of the plant. The distance from the farmers to the plants can be found in table 35 – *Distance between the farmers*.

Farmer	Km	Km per trip
Christian Jørgensen	15	30
Niels Mejnertsen	20	40
Peter Mejnertsen	17	34

Table 35 - Distance between the farmers and the plant

Plant	Dranco	Sauter	Agrikomp	Combigas	Aikan
Christian Jørgensen					
Harvesting	984.568 kr.	404.516 kr.	275.882 kr.	492.284 kr.	617.130 kr.
Loading	57.544 kr.	21.194 kr.	19.039 kr.	28.772 kr.	37.328 kr.
Transportation	349.790 kr.	107.608 kr.	63.798 kr.	419.000 kr.	140.315 kr.
Storage	295.251 kr.	100.671 kr.	71.591 kr.	268.469 kr.	149.094 kr.
Total cost	**1.687.154 kr.**	**633.990 kr.**	**430.250 kr.**	**1.208.525 kr.**	**943.868 kr.**
Niels Mejnertsen					
Harvesting	765.382 kr.	404.516 kr.	340.108 kr.	382.691 kr.	468.114 kr.
Loading	69.504	17.594 kr.	40.036 kr.	34.752 kr.	47.715 kr.
Transportation	631.414 kr.	115.158 kr.	250.241 kr.	686.882 kr.	228.172 kr.
Storage	385.983 kr.	81.873 kr.	181.230 kr.	330.804 kr.	288.172 kr.
Total cost	**1.852.285 kr.**	**619.142 kr.**	**811.616 kr.**	**1.435.130 kr.**	**1.015.664 kr.**
Peter Mejnertsen					
Harvesting	900.659 kr.	956.411 kr.	427.743 kr.	450.330 kr.	533.913 kr.
Loading	72.172 kr.	32.012 kr.	27.514 kr.	36.086 kr.	73.956 kr.
Transportation	615.792 kr.	200.876 kr.	215.988 kr.	570.812 kr.	498.729 kr.
Storage	423.635 kr.	160.489 kr.	155.119 kr.	326.662 kr.	381.188 kr.
Total cost	**2.012.259 kr.**	**1.349.787 kr.**	**826.364 kr.**	**1.383.889 kr.**	**1.487.787 kr.**
Total cost					
Total cost	**5.067.084 kr.**	**2.588.071 kr.**	**2.280.535 kr.**	**3.420.289 kr.**	**3.237.350 kr.**
Cost per ton FM	124,71 kr.	248,85 kr.	181,93 kr.	75,64 kr.	157,91 kr.
Cost per ton DM	468,61 kr.	764,34 kr.	483,98 kr.	517,13 kr.	431,24 kr.

Table 36 – Annual cost for delivering the biomasses to the biogas plant

As seen in the tables, the costs are in most cases similar. But in the plant offer from Sauter, the costs for acquiring the biomasses from Peter Mejnertsen are significantly higher than the costs from the two other farmers. This is because Peter Mejnertsen is the only farmer that has yellow mustard in his crop rotation, which is one of the main components in the biomass composition to the biogas plant. The amount of yellow mustard in this plant offer is 20 times larger than the amount stated in the case. This amount is too high for Peter Mejnertsen to grow on his own farm, which in reality would mean that the other farmers should work this crop into their rotation, in order to get the needed amount of biomass. But in these calculations it is seen as a reality that Peter Mejnertsen would be capable of having the total amount in his crop rotation. This is selected, in order to be able of comparing the results from all plant offers, and due to the fact that the costs of handling and transporting the biomass, and the yield generated from the fertilizer, would be highly similar. The case is similar for the Agrikomp plant where Niels Mejnertsen and Peter Mejnertsen have a larger part of the biomass than Christian Jørgensen. These facts will also be seen in the costs of delivering the degasified biomass to the farmers, which are found in the following table 37 – *Annual cost for delivering the degasified biomass to the farmers*.

Plant	Dranco	Sauter	Agrikomp	Combigas	Aikan
Christian Jørgensen					
Loading	53.360 kr.	10.301 kr.	7.256 kr.	0 kr.	7.258 kr.
Transportation	314.823 kr.	81.260 kr.	48.779 kr.	395.507 kr.	42.822 kr.
Storage	278.628 kr.	63.929 kr.	40.844 kr.	195.796 kr.	37.899 kr.
Total cost	**646.811 kr.**	**155.489 kr.**	**96.880 kr.**	**591.303 kr.**	**87.980 kr.**
Niels Mejnertsen					
Loading	63.191 kr.	8.246 kr.	18.321 kr.	0 kr.	8.213 kr.
Transportation	372.824 kr.	69.135 kr.	114.064 kr.	395.507 kr.	48.457 kr.
Storage	329.960 kr.	53.197 kr.	98.623 kr.	195.796 kr.	42.886 kr.
Total cost	**765.975 kr.**	**130.578 kr.**	**231.008 kr.**	**591.303 kr.**	**99.556 kr.**
Peter Mejnertsen					
Loading	93.701 kr.	17.075 kr.	27.552 kr.	0 kr.	23.529 kr.
Transportation	552.839 kr.	134.703 kr.	185.216 kr.	500.218 kr.	138.820 kr.
Storage	489.278 kr.	105.973 kr.	155.085 kr.	247.632 kr.	112.860 kr.
Total cost	**1.135.818 kr.**	**257.752 kr.**	**367.854 kr.**	**747.851 kr.**	**285.209 kr.**
Total cost					
Total cost	**2.548.604 kr.**	**543.820 kr.**	**695.742 kr.**	**1.930.456 kr.**	**472.745 kr.**
Cost per ton degasified biomass	72,72 kr.	52,29 kr.	67,57 kr.	43,21 kr.	72,73 kr.

Table 37 – Annual cost for delivering the degasified biomass to the farmers

Plant	Dranco	Sauter	Agrikomp	Combigas	Aikan
Cost for delivering the biomass	5.067.084 kr.	2.588.071 kr.	2.280.535 kr.	3.420.289 kr.	3.237.350 kr.
Cost for delivering the degasified biomass	2.548.604 kr.	543.820 kr.	695.742 kr.	1.930.456 kr.	472.745 kr.
Total cost in the symbiosis	**7.615.689 kr.**	**3.131.891 kr.**	**2.976.277 kr.**	**5.350.745 kr.**	**3.710.095 kr.**

Table 38 - Total annual cost in the symbiosis

It is seen in table 38 – *Total annual cost in the symbiosis,* that the costs related to the symbiosis with the different plants, are lowest for the biogas plants handling the lowest amount of biomass. But the costs are not significantly higher for the slurry based plants, where the amount of biomass is almost four times larger, than the smaller non-slurry and garage based plants. The reasons for this, is that the costs for handling and transporting slurry are lower than the costs for handling and transporting solid biomasses. The costs per ton are therefore significantly lower.

3.5 EARNINGS IN THE SYMBIOSIS

The manufactures have calculated what the outputs of biogas and degasified biomass are from their offered plants[28]. This can be used in order to find the output of biogas and fertilizer, from the plant offers, and herby the earnings that is generated from using the plant in the symbiosis. This section is divided into two sub-sections, the first calculating the earnings from the biogas plants, the second sub-section calculating the earnings generated by the farmers based on the use of degasified biomass.

3.5.1 Earnings from the biogas plant

The plant offers states the amount of biogas produced from each of the biomasses used, in their plant solution. The values stated by the plant manufactures, have been compared to the theoretically calculated values and the practical measured values, found in the literature review. The comparing of values can be found in appendix 16 – *Comparing biogas output*. The comparing showed that the values are highly similar, and the values from the plant manufactures are therefor found to be realistic. In the following three tables the energy production, consumption and sellable energy can be seen.

Plant	Dranco	Sauter	Agrikomp	Combigas	Aikan
Biogas production	4.228.302 Nm3	1.633.956 Nm3	1.705.717 Nm3	2.499.042 Nm3	1.253.681 Nm3
Biogas production per ton FM	104,07 Nm3	157,11 Nm3	136,08 Nm3	52,37 Nm3	61,16 Nm3
Biogas production per ton DM	391,03 Nm3	482,62 Nm3	362,01 Nm3	377,86 Nm3	167,00 Nm3
Gas engine run time %	95,00*	91,44	92,00	95,00*	95,00*
Total energy production	23.387.840 kWh*	8.967.905 kWh	8.760.000 kWh	14.904.285 kWh	7.114.555 kWh*

Table 39 - Total annual production of biogas and energy - *Estimated

Plant	Dranco	Sauter	Agrikomp	Combigas	Aikan
Gas engine electricity	46,00*	40,19	46,00	42,00	46,00*

[28] Appendix 16 – *Comparing biogas output*

conversion %					
Electricity production	10.220.486 kWh*	3.295.622 kWh	3.707.232 kWh	5.946.810 kWh	2.838.708 kWh*
Electricity consumption	870.485 kWh	210.947 kWh	185.362 kWh	350.000 kWh	250.000 kWh
Electricity for sale	9.350.001 kWh	3.084.675 kWh	3.521.870 kWh	5.596,810 kWh	2.588.708 kWh
Earnings from sale	**11.497.300 kr.**	**3.685.067 kr.**	**4.207.357 kr.**	**6.686.156 kr.**	**3.092.566 kr.**

Table 40 – Annual production and earnings from electricity - *Estimated

Plant	Dranco	Sauter	Agrikomp	Combigas	Aikan
Gas engine heat conversion %	33*	41,88	33	43	33*
Heat production	7.332.088 kWh	3.434.204 kWh	2.659.536 kWh	5.946.810 kWh	2.838.708 kWh
Heat consumption	2.995.920 kWh*	1.441.800 kWh	1.450.656 kWh	2.442.000 kWh	500.000 kWh
Heat for sale	4.336.168 kWh	1.992.404 kWh	1.208.880 kWh	3.646.400 kWh	2.406.296 kWh
Earnings from sale	**970.434 kr.**	**445.900 kr.**	**270.547 kr.**	**816.064 kr.**	**538.529 kr.**

Table 41 - Annual production and earnings from heat - *Estimated

In the following table can the total earnings generated from the biogas plant is calculated.

Plant	Dranco	Sauter	Agrikomp	Combigas	Aikan
Earnings electricity	11.497.300 kr.	3.685.067 kr.	4.207.357 kr.	6.686.156 kr.	3.092.566 kr.
Earnings from heat	970.434 kr.	445.900 kr.	270.547 kr.	816.064 kr.	538.529 kr.
Total earnings	**12.140.292 kr.**	**4.130.967 kr.**	**4.477.904 kr.**	**7.502.220 kr.**	**3.631.095 kr.**
Earnings per ton FM	298,80 kr.	397,20 kr.	357,23 kr.	157,22 kr.	117,12 kr.
Earnings per ton DM	1122,74 kr.	1220,01 kr.	950,31 kr.	1134,29 kr.	483,69 kr.

Table 42 - Total earnings from the biogas plants

3.5.2 Earnings from the farmers

Based on the knowledge about the amount of degasified biomass, and the crop rotation from the farmers, the earnings from using the degasified biomass as fertilizer can be found. The crops are supplied with fertilizer after the yield response and generating earnings, based on the yield response. As found in section 2.5.1.1.3.2 - *Yield response to fertilizer*, the yield response is higher with a low amount of fertilizer, and this will therefore influence the optimal fertilizer supply for the fields at the farmers. In order to find the optimal supply of fertilizer, based on the amount of fertilizer available, a calculator developed by VFL is used to determine the optimal fertilizer supply at the three farmers. In table 43 – *Annual amount of NH4-N and earnings from the fertilizer,* the amount of available degasified biomass and the content of NH4-N in the fertilizer from each biogas plant can be found. The amount of fertilizer available for the three farmers is calculated based on the distribution key found.

Plant	Dranco	Sauter	Agrikomp	Combigas	Aikan
Degasified biomass	35.042 ton	8.275 ton	10.297 ton	44.671 ton	6.500 ton
NH4-N	155,76 ton	40,19 ton	58,04 ton	157,26 ton	89,70 ton
NH4-N per ton	4,44 kg	4,86 kg	5,64 kg	3,52 kg	13,80 kg
Earnings from the yield	**5.921.425 kr.**	**2.904.324 kr.**	**3.502.753 kr.**	**6.089.364 kr.**	**4.208.262 kr.**
Earnings per ton degasified biomass	168,98 kr.	350,97 kr.	340,17 kr.	136,31 kr.	647,42 kr.

Table 43 – Annual amount of NH4-N and earnings from the fertilizer

As seen in the table the plant offers handling the highest percentage of organic biomasses is getting the highest content of ammonium nitrogen in the degasified biomass. Therefor is the earnings per ton degasified biomass higher for these biogas plants, that the biogas plants where conventional slurry is the primarily biomass.

3.6 PROFITABILITY IN THE SYMBIOSIS

Now that the costs and earnings related to the three areas have been found, the profitability in the symbiosis with the plant offers can be calculated.

Plant	Dranco	Sauter	Agrikomp	Combigas	Aikan
Biogas plant					
Earnings	12.140.292 kr.	4.130.967 kr.	4.477.904 kr.	7.502.220 kr.	3.631.095 kr.
Cost	11.273.887 kr.	3.484.889 kr.	3.894.901 kr.	3.758.431 kr.	15.380.800 kr.
Profit	**866.405 kr.**	**646.078 kr.**	**589.003 kr.**	**3.743.789 kr.**	**-11.749.705 kr.**
Organic farmers					
Earnings	5.921.425 kr.	2.904.324 kr.	3.502.753 kr.	6.089.364 kr.	4.208.262 kr.
Cost	1.226.470 kr.	266.245 kr.	345.975 kr.	1.116.775 kr.	227.500 kr.
Profit	**4.694.956 kr.**	**2.638.079 kr.**	**3.156.778 kr.**	**4.972.589 kr.**	**3.980.762 kr.**
The symbiosis					
Joint profit	5.561.361 kr.	3.284.157 kr.	3.739.781 kr.	8.716.378 kr.	-7.768.942

					kr.
Cost	7.615.689 kr.	3.131.891 kr.	2.976.277 kr.	5.350.745 kr.	3.710.095 kr.
Profit from the symbiosis	**-2.054.327 kr.**	**152.267 kr.**	**763.504 kr.**	**3.365.633 kr.**	**-11.479.038 kr.**
Profit per ton FM	-50,56 kr.	14,64 kr.	60,91 kr.	70,54 kr.	-559,95 kr.
Profit per ton DM	-189,89 kr.	44,97 kr.	162,04 kr.	524,35 kr.	-1.529,07 kr.

Table 44 - Profitability in the symbiosis with the plant offers

As it can be seen in table 44 – *Profitability in the symbiosis with the plant offers*, three of the plant offers is generating revenue. The plant offers from Dranco and Aikan is not found interesting for further investigations, due to the fact that profitability is calculated based on a best case scenario. The plant offer from Sauter is also only generating low profit, which may be considered as too low, in order to make it interesting for the farmers. The case is similar for the Agrikomp plant, where the profit also is found to be low, when dividing the profit on the three farmers. But even though these two plant offers is only capable of generating low profit, the plants is investigated further. The Combigas plant is generating significantly higher profit, which makes the plant interesting. But the plant offers is using a large amount of slurry, which is leading to the understanding that a status as organic cannot be obtained.

3.7 DISTRIBUTION OF THE COST AND PROFIT IN THE SYMBIOSIS

The three plants from Sauter, Agrikomp and Combigas, has been selected for further investigations, due to the fact that all plant offers was able of generating profit in the best case scenario. Following the method determined in section 2.6.5.2 – *Distribution key to the costs and profit in the symbiosis*, the costs and profit from the symbiosis is divided between the two parties in the symbiosis. Hereby, the profit for each of the two parties in the symbiosis can be calculated.

Plant	Sauter	Agrikomp	Combigas
Percentage of the generated profit			
Biogas plant	19,67 %	15,59 %	42,95 %
Organic farmers	80,33 %	84,41%	57,05%
Cost in the symbiosis			
Biogas plant	616.123 kr.	463.978 kr.	2.298.209 kr.
Organic farmers	2.515.767 kr.	2.512.299 kr.	3.052.536 kr.
Profit from the symbiosis			
Biogas plant	29.955 kr.	119.024 kr.	1.445.580 kr.
Total return of investment	10,24 %	10,66 %	18,41 %
Organic farmers	122.312 kr.	644.479 kr.	1.920.053 kr.

Table 45 - Profit for each of the two parties in the symbiosis

The symbiosis with the Sauter and Agrikomp plants are only generating low revenue for the farmers, and only a small amount of additional profit to the investor. It must therefore be found highly questionable, if any of the farmers is interested in the symbiosis with the biogas plants. The Combigas plant is generating a better profit for the farmers, and for the biogas plant, but the question is still whether the profit is high enough for the farmers to be interested in the symbiosis.

3.8 SCENARIOS IN THE SYMBIOSIS

The previous calculations in the business case have been based on a best case scenario, where all heat was sold, and where no fertilizer ability was lost during the transportation and handling of the biomasses. But the best case scenario is not expected to become a reality in the Sjællandcase. This is due to the location of the biogas plant, and the fact there is a lot of transportation and handling of the biomasses in the symbiosis. Therefor is it important to calculate the results if the conditions not are as in the best case scenario. In table 46 – *Scenarios in the symbiosis*, is three scenarios with the symbiosis in the Sjællandcase presented. The first scenario is based on the fact that no heat can be sold, the second on the fact that the degasified biomass is losing 20 percent of the fertilizer ability. The third and last scenario is based on the fact that both conditions from the two other scenarios are present.

Plant	Sauter	Agrikomp	Combigas
No earnings from heat			
Profit from the symbiosis	-293.633 kr.	492.956 kr.	2.549.568 kr.
Return of investment biogas plant	9,83 %	10,25 %	17,86 %
Profit for the farmers	-293.633 kr.	448.540 kr.	1.604.698 kr.
Loss of 20 percent fertilizer ability			
Profit from the symbiosis	-332.259 kr.	231.830 kr.	2.622.375 kr.
Return of investment biogas plant	9,38 %	10,23 %	17,16 %
Profit for the farmers	-255.573 kr.	189.706 kr.	1.390.907 kr.
Loss of 20 percent fertilizer ability and no earnings from heat			
Profit from the symbiosis	-778.156 kr.	-38.716 kr.	1.806.310 kr.
Return of investment biogas plant	9,47 %	9,98 %	14,30 %
Profit for the farmers	-712.012 kr.	-34.596 kr.	1.067.348 kr.

Table 46 - Scenarios in the symbiosis

In table 46 – *Scenarios in the symbiosis,* it can be seen that the scenarios decreases the profit generated from each of the plant offers. The Sauter plant offer is generating no profit in the three scenarios, which must lead to the fact that this plant will not be profitable in reality. The Agrikomp plant is generating a small profit in the first two scenarios, but again is the question whether this profit is large enough to make it interesting for the farmers. In the third scenarios, the Agrikomp plant is generating a negative profit, which also indicates that it is questionable whether this plant solution can generate a profit. The Combigas solution is generating a profit in all three scenarios, but the profit is found to be at a level where it is questionable whether the farmers find it interesting to develop a symbiosis.

4. DISCUSSION

The findings that have been made throughout this project will now be used in order to discuss the areas that are found important during the investigations. The discussion will be divided in to three sections. The first will be a discussion regarding the findings in the thesis, hereby discussing the possible errors and important factors with the findings. The second section will contain a discussion of the profitability fond in the symbiosis, based on the result from the case study. The third section will contain a discussion on the synergy that can be found towards the national political interest, and suggestions to achieve a better synergy based on the findings from the investigations. The fourth and last section will contain a discussion on the biogas project development approach found in VFL, in relation to the experience found in this project. This will be done in order to evaluate their approach to a biogas project.

4.1 THE FINDINGS IN THE THESIS

This section will contain a discussion on the findings and calculations that have been made in this thesis.

4.1.1 Calculation of output from the biogas plant

The theoretical found output from the biogas process is found based on calculations from the researcher. The calculations is based on substance and nutrient content found in the Norfor feed table. The calculations made are on the biogas and fertilizer output from the biogas process. This section will therefore contain a discussion on the calculations of these two outputs from the process, due to the great importance of the calculations in the evaluations of the profitability in the symbiosis.

4.1.1.1 Calculating the biogas output

The calculations are made based on the content of protein, fat and carbohydrates, where the carbohydrates are divided into celluloses, strach, sugar, and remaining carbohydrates. The degradability, methane content and the weight of the molecules of the substances in the biomasses are found based on theory. A possible error in the calculations could therefore be that the values used in the calculations will be different when being conducted in practice. This has also been tested in practical studies (Ladatut, 2012), from where the tests only showed minor deviations to the theoretical values. Another area that could contain an error for the calculations is the simplification of the substance content in the biomasses. The content of substance has been simplified in relation to the content that could be found in the Norfor feed table, hereby accepting that the remaining fraction of the organic dry matter is similar carbohydrates. Therefor the remaining fraction is calculated as one kind of carbohydrates, even though knowing that the remaining fraction contains other carbohydrates. This was accepted because it was found to be a too difficult task to find the remaining content of substances in the dry matter content. The degradability and methane content of carbohydrates is therefor based on the values from a specific carbohydrate, knowing that these values not are real for all the carbohydrates.

The found theoretical biogas output has been verified by to methods. The one was to find practical trails made with similar biomasses, hereby comparing the amount of output from the theoretical calculations and practical trails. The result from the two methods was similar for most of the biomasses, but the biomasses from straw had a larger output of biogas in the theoretical method, than in the practical trails. This could be due to many things, but the main reason that highly could influence the result from straw is the content of lignin. As found in the literature review, lignin is a larger fraction of straw, which cannot be converted into biogas. The theoretical calculations do not take the specific content of lignin into consideration, but it has been accepted that the lignin content is at 40 percent. The content in the practical trail could be at a higher level, which would lead to a lower biogas output from the biomass. Another aspect that is relevant when discussing the comparison to the practical trails is the missing knowledge about how the tests are conducted. The lacking knowledge could mean that the tested biomass is different to the biomass calculated theoretical based on the values from the NorFor feed table. Also could the biomasses in the practical trails could be tested over a period of time or under conditions, which increases or decreases the output of biogas. How big an influence these factors have on the output is impossible to know, and therefor is it also impossible to tell what the specific reason to the deviations is. A suggestion would be to find the biomasses relevant for organic biogas plants, and to test the biomasses in order to get the substance content for the theoretical calculations, and to test the same biomass in the practical trail. Hereby will the methods in the practical method be known, and the biomasses used in the two methods would be the same. This would enable a more specific analysis, regarding the comparison of the practical and theoretical output.

The other method that is used for verifying the theoretical biogas output is the theoretical output found from the plant manufactures. The manufactures were asked to state the output from each of the biomasses in their plant offer, hereby to compare the values to the theoretical calculated values. The output of biogas from the biomasses found by the manufactures can be found in appendix 16 – *Comparing biogas output*. The values found by the manufactures are similar to the values found from the theoretical calculations, which indicates that a similar approach could be used by the manufactures. The only biomass where some of the manufactures found a different value is for separated grains. This could be due to the fact that they do not have knowledge about what kind of biomass this is, or that they have values for a biomass that they find similar to separated grains.

4.1.1.2 Calculating the fertilizer output

The theoretical calculations of the fertilizer output is based on the nutrient value found in the NorFor feed table, and the content of nitrogen that is expected to be transformed from organic to inorganic during the biogas process. The amount of nutrients in the degasified biomass is found based on the degradability of the biomasses. There is a lacking focus on this area, due to biogas production being the main area of the biogas plants. Therefor is the knowledge about this area highly limited. The conversion rate, that has been accepted to be at 50 percent, is a guess from a range of experts no theory is found to be stating a method for determining the conversion rate during a biogas process. The guesses have been on a level from 45 to 80 percent, but are found to be unknown, based on the fact that the specific biomasses and the environment in the process will determine the conversion rate. The only method for determining the specific conversion rate is to measure the nutrient content in the input and output material, hereby calculating the conversion rate. The fact that the conversion rate is only a guess, will also lead to the fact that the output of inorganic fertilizer is a guess. Therefor it is known that the fertilizer output could be different in a practical trail, than the amount calculated based on the found theoretical knowledge.

4.1.2 Cost in the case study

The cost in the calculations of the profitability in the Sjællandcase is made based on cost estimations found in the literature review, and from the offers received from the manufactures. The costs found in the literature review are calculated by the researcher based on the knowledge received from his experience, and through conversations with experts on the areas. There are many cost related to the transportation and handling of the biomasses in the symbiosis. These costs have been simplified, in order to make the calculations easier understandable. But this has also led to the fact that the calculations could be deviating from what the cost would actually be, if it has been found specifically. E.g. has it been accepted that the cost for making silage is the same for all silage crops, even though knowing that some silage crops is more costly to harvest than other. But in order to verify the cost found in relation to the transportation and handling of the biomasses, the values calculated have been verified by Karen Jørgensen[29]. During the verification of the costs, it was also found that this area has a great potential for optimization. It was although not selected to optimize the cost found in the case, due to the fact that the costs was found to be realistic, and that this area is not the object of this project.

The cost for transportation is related to the location found for the biogas plant. The location of the plant has been found in cooperation with the farmers from the case. It has been selected that the plant should not be placed at one of the farmers, which is influencing the cost for transporting the biomasses in the symbiosis. If placing the biogas plant at one of the farmers the profitability would be different. The difference in transportation cost can be seen in table 47 – *Transportation cost affecting the profitability in the symbiosis*.

Plant	Sauter	Agrikomp	Combigas
Sjællandcase transportation cost	708.740 kr.	878.086 kr.	2.967.926 kr.
Biogas plant located at Christian Jørgensen			
Transportation cost	405.406 kr.	530.720 kr.	1.421.745 kr.
Symbiosis profit	376.781 kr.	1.086.032 kr.	4.519.735 kr.
Improvement in profit	224.515 kr.	322.529 kr.	1.154.102 kr.
Biogas plant located at Niels Mejnertsen			
Transportation cost	841.723 kr.	894.654 kr.	2.986.164 kr.
Symbiosis profit	134.441 kr.	902.777 kr.	3.455.077
Improvement in profit	-17.824 kr.	139.503 kr.	89.444 kr.
Biogas plant located at Peter Mejnertsen			
Transportation cost	925.671 kr.	1.216.801 kr.	4.383.494 kr.
Symbiosis profit	-82.219 kr.	335.570 kr.	2.188.350 kr.
Improvement in profit	-234.486 kr.	-427.932 kr.	-1.177.282 kr.

Table 47 – Transportation costs affecting the profitability in the symbiosis

As is seen in table 47 – *Transportation cost affecting the profitability in the symbiosis,* locating the biogas plant at Christian Jørgensen would give a better profitability in the symbiosis. Locating the biogas plant at the two other farmers gives the same or a worse profitability in the symbiosis. The location in the business case was selected due to the good infrastructure at the location, and is therefore expected to be the best location for the plant. The infrastructure at the farmers is unknown, but are for them all expected to be worse than

[29] Conversation with Karen Jørgensen at VFL – Appendix 4 – Interviews/conversations

at the selected location. Therefore, is the selected location still found to be the optimal location for the biogas plant in the Sjællandcase.

4.1.3 Optimal crop rotation

In the Sjællandcase the biomasses that are available in the three farmer's current crop rotation was found. The farmers identified the biomasses, without specific knowledge about the biogas output from the biomasses. It was also stated in the early phases of the biogas project that a precondition to the project was that the farmers could be able to maintain their current crop rotation when acting as partner in the symbiosis. In later discussion with Peter Mejnertsen, it was found that the farmers would be able to change their crop rotation if there was a better economy in supplying the biogas plant with different composition of the biomasses. Therefor it is of great interest to know which of the crops that generates the most biogas and fertilizer, in order to have this as an influential factor when selecting the crop rotation. In table 48 – *Biogas and fertilizer output from the Mesophilic biogas process,* the output of biogas and fertilizer from the biomasses in the Sjællandcase can be found.

Biomass (Mesophilic)	Methane	Biogas	NH4-N
Unit	CH4 Nm3/ton	Nm3/ton	Kg/ton
Clover grass silage	107,2	198,66	7,06
Straw + clover grass silage	123,83	234,95	5,87
Seed grass straw	191,67	370,69	7,44
Straw	204,42	397,56	4,49
Permanent grass silage	103,01	191,63	6,49
Carrots + tops	37,46	71,63	2,77
Regrown seed grass silage	82,88	151,55	6,38
Separated grains	203,01	381,84	9,35
Yellow mustard silage	30,14	60,27	2,21

Table 48 - Biogas and fertilizer output from the Mesophilic biogas process

As seen in table 48 – *Biogas and fertilizer output from the Mesophilic biogas process*, the output of biogas is high for the straw biomasses, and the output of fertilizer is also high for the seed grass straw. These aspects make the straw biomasses highly interesting for the symbiosis. But there are factors that need to be taken into consideration when looking on the output from the biomasses. The factors are the content of dry matter and nitrogen in the biomass. The high dry matter content in straw, makes the biomass un suitable for a wet anaerobic digestion plant, where the biomass is only allowed to have a dry matter content of maximum 40 percent. Also will the content of nitrogen be inhibiting to the process, and this should therefor also be taken into consideration, when finding biomasses in the crop rotation. Therefor is it of great importance that these two factors are considered when finding biomasses in the crop rotations. The focus can therefore not only be on the output of biogas and fertilizer from the biogas plant. Another factor that needs to be considered is the regular factors for selecting a crop rotation.

4.2 PROFITABILITY IN THE SYMBIOSIS

This section will be discussing the result found in the business case for the Sjællandcase. This will be done in order to find the areas that have great influence on the profitability found in the Sjællandcase.

4.2.1 The result of the business case

As seen in the business case only three plant offers generates a profit in the symbiosis, when the conditions are best case. Based on this it is found that the biogas plants that are capable of generating a profit is the biogas plants using wet anaerobic digestion, as the technical solution. But as it was described in the business case, the solution from Combigas is using a large amount of conventional slurry. The amount of slurry used for the biogas plant is leading to the understanding, that the biogas plant would not receive the status as organic, and that the degasified biomass therefor not will be organic fertilizer. This fact is making the biogas plant uninteresting in relation to the scoop of this project. But the solution from Combigas will work as a benchmarking plant, for the other plants that are expected to get the status of organic. This leaving only the Sauter and Agrikomp plants as interesting for the Sjællandcase.

The profit from the biogas plants solutions is changing when the selling of heat is withdrawn from the result. The profit it the symbiosis with the Sauter biogas plant is changing to generating a negative profit, where the yearly return of investment will be lower than the 10 percent stated as a precondition. The same is the case with the Agrikomp plant, if the loss of fertilizer ability is at 20 percent and no heat is sold. The Combigas plant is capable of generating a profit in all of the scenarios, but at stated above the plant is uninteresting due to the great use of conventional slurry. As stated in the business case, the scenario that is found most realistic is the scenario where there is a loss of 20 percent fertilizer ability and no heat can be sold from the biogas plant. Following this presumption, none of the plants are capable of solving the objective of the project. It should although be stated that the loss of fertilizer ability would lead to a different fertilizer supply, due to the yield response the fertilizer. But the change is expected to be on a small level, therefor is no significant impact expected on the total result.

The question is how the profitability in the Sjællandcase would change, if the investor would accept a lower annual return of investment. In table 49 – *Profitability in the symbiosis at different annual return of investment* is the symbiosis profitability found, if the annual return of investment is changed to a lower level. The scenarios selected, is the scenario found most realistic, where there is a loss of 20 percent fertilizer ability and where no heat is sold.

Plant	Sauter	Agrikomp	Combigas
9 %	-653.858 kr.	141.323 kr.	1.978.270 kr.
8 %	-529.599 kr.	321.363 kr.	2.150.229 kr.
7 %	-405.260 kr.	501.403 kr.	2.322.189 kr.
6 %	-280.962 kr.	681.443 kr.	2.494.148 kr.
5 %	-156.663 kr.	861.483 kr.	2.666.107 kr.

Table 49 - Profitability in the symbiosis at different annual return of investment

As is can be seen in table 49 – *Profitability in the symbiosis at different annual return of investment,* the lowering of the return of investment, only makes the profitability a small amount better. Lowering the return of investment is also found to be unrealistic, due to the fact that the investor would easily be able of finding more profitable investments, with a lower risk.

4.2.2 Offers from the plant manufactures

The offers received were off highly different kind and quality, and a range of further questions was asked the manufactures in order to be able to compare the offers received. Even though asking the further questions, not all manufactures was able of supplying the needed answers in order to compare the biogas plant offers. As seen in the business case the researcher in cooperation with experts has estimated several costs, due to the lack of answers in the offers. The estimates are made based on the answers from the other offers, and knowledge from the experts. But it is difficult to tell whether the estimate costs would be found to be the same if estimated by the manufactures. But in the project the estimated costs are accepted, due to the fact that they are needed in order to compare the plant offers in a similar framework.

Some of the costs stated in the plant offers are found to be unrealistic in comparison to the other plant offers, and from the knowledge of the experts. The cost for maintaining the gas engine is for all offers estimated based on the offer from Agrikomp. The only other offer that was estimating a cost for maintaining the gas engine was the offer from Sauter. But the estimated cost from Sauter was found to be unrealistic low, which is due to the fact that the purchase of a new engine was not in calculated in the offer. Based on knowledge from Holger Schulz[30] a gas engine is expected to have a life time of five years, which would mean that two new gas engines is needed during the payback period of 15 years. In the maintenance cost from Agrikomp the purchase of two new gas engines is included, and therefor is this maintenance cost found more realistic. Also is the maintenance of the Aikan and Dranco plant estimated, which is done based on the maintenance need from the Sauter biogas plant. This is due to the fact that these three biogas plants have a similar complexity in the use of technologies. The maintenance cost stated by Combigas is found to be low very low, which is due to the maintenance cost in the offer only being stated over a period of the first five years. The cost for the machinery that is needed on the biogas plants is for the Dranco, Agrikomp and Combigas estimated based on knowledge from Holger Schulz[31]. The amount of machinery that is needed for the specific biogas plant is hard to estimate, but is not found to have a great influence on the profitability in the offers. The last cost that is estimated is the labor cost in the Dranco offer, which is based on the offer from Sauter, due to the similar level of technology use in the two offers.

The reason for the missing estimations in the offers could be the fact that the manufactures only have used a small amount of time on the offers. The manufactures is expected to only use a limited amount time on the offers, due to the fact that no sale is expected based on the offers. Also are the manufactures only expected to come up with answers to the questions they are asked directly in the questionnaire. These two facts have been taken into consideration when making the questionnaire to the plant manufactures, and the answers is there for found to be as reliable as possible. If the costs that are found to be unrealistic in the offers were converted into costs found realistic, only the plant offer from Combigas would change significantly. The annual costs in the Combigas offer would increase by approximately 500.000 kr.

When analyzing the plant offers, it is quickly clear why the plant offer from Aikan generates such a bad profitability. The amount of biogas output from the biomasses in the plant is only half of what the other plants are able of producing. This combined with the fact that the biogas plant is much more expensive that the other biogas plants, is leading to the bad profitability in the plant offer. Also it is found that the offers from Dranco and Combigas are not able of using only the organic biomasses available in the Sjællandcase. Both plants need a high amount of slurry in order to lower the average dry matter content in the biomass, so that the biomass could be processed in the biogas plants. The percentage of slurry needed for both biogas plants is at a level that is expected to make them unable of achieving the status of fully organic. The two manufactures is not able of making a biogas plant that can handle the biomasses in the Sjællandcase without the high amount of conversional slurry.

[30] Appendix 11 – Interview with Agrikomp
[31] Appendix 11 – Interview with Agrikomp

4.2.3 Distribution key in the Sjællandcase

As found in the retroductive synthesis, two distribution keys are needed in the symbiosis. The distribution key for the costs and profits is based on the amount of profit each party is generating for the symbiosis. In the business case for the Sauter and Agrikomp plants offers, the main share of profit is generated from the farmer. The farmers are therefore obligated to cover the biggest amount of costs, but also to receive the largest amount of profit. For the Combigas plant is the share more equal. But the question is whether this is the right way of dividing the costs and profits in the symbiosis. The investor has already received a 10 percent return of investment, from the annual cost to the biogas plant. It would therefor seam more appropriate that the total amount of profits generated from the symbiosis was given to the farmer, in order to make the symbiosis interesting for them. But as stated in the case study, the investor is expected to get a minimum of 10 percent of annual return of investment, and the investor is therefore not expected to agree on the presumption. The level of profit for the farmers is in the business case at a level where their interest would be at a minimum. The work related to being a part of the process, will only generate a small profit, so even though they have a very small risk, the symbiosis seem to be uninteresting for them.

Another issue related to the need for a distribution key is the deliverance and distribution of the biomasses in the symbiosis. The biomasses delivered from the farmers to the biogas plant, needs to be done based on a binding contract. This is due to the fact that a too high average dry matter content could destroy the process. Another issue is the average content of nitrogen in the biomass. The content needs to be at a minimum in order not to be inhibiting for the process. A binding contract on the amount of biomass each farmer should deliver to the biogas plant needs to be established. Within the contract it should be stated how high the dry matter and nitrogen content is allowed to be in the biomass. The farmers want to get as high a content of NH4-N out of the degasification of the biomasses, but this cannot be their object when delivering biomasses for the biogas plant. In the binding contract the amount of biomass from each of the farmers should be stated, and hereby also the amount of dry matter and nitrogen content there is in the biomass delivered. The amount stated in the contract should make it possible for deviations in each of the three parameters, amount of biomass, dry matter content and nitrogen content. The yield from the farmers is influenced by a range of factors, from where most of them cannot be affected by the farmers. Therefor is the practical yield and content of dry matter and nitrogen, not going to be the same ass the amounts found in theory. This fact is the reason a level of deviation is needed in the binding contract.

4.3 SYNERGY TOWARDS NATIONAL POLICY

In this section the synergy towards national policy will be discussed, also a discussion will be about the needed local acceptance.

4.3.1 Similar goals

As it is found in the introduction the goals from the national policies is similar to the goals found in the symbiosis. Based on this it is expected that a synergy between the national policies and the symbiosis can exist. This is especially seen in the fact that the government has made the biogas taskforce, and the fact that the biogas taskforce was participating in the organic biogas workshop. By this focus on organic biogas, the government shows interest in the area where the symbiosis between organic farmers and biogas plant exists, and they are therefor expected to have an interest in the symbiosis. The goals for doubling the area with organic agriculture in 2020 will be easier to achieve if the symbiosis, makes more organic fertilizer available for the organic farmers. This understanding is also applicable for the 20-20-20 goals, where biogas is already expected to play a role. Hereby is it understood that a synergy between the two areas would be very desirable for the government.

But as found in the interviews with the farmers and the organic biogas workshop, it is hard for the farmers to see how the biogas taskforce is helping them achieve the stated goals for 2020. The main problem found is the difficulties for the farmers to come from the initiating phase of a biogas project and to the building phase of a biogas plant. There is a lot of work and investigations needed in between the two phases, which are highly costly and time consuming for the commissioning party. The investment the commissioning party makes in this work is not coming back, if the biogas project is killed before the building phase. The commissioning party is therefore taken a great risk when investing in the work and investigations between these two phases. It is found in this study that this is a big barrier for many of the biogas projects, and that this is one of the areas where the biogas taskforce should support the biogas projects. A support from the biogas taskforce would make the risk lower for the commissioning party, and possibly make more biogas projects possible. But there must be a reason for the biogas taskforce not being able of supporting the project, even though this is the object of the biogas taskforce.

During the biogas taskforce it was observed how the biogas taskforce was acting when being presented with the problems in organic biogas. The biogas taskforce was unaware of many of the problems the commissioning party is facing when initiating a biogas project. Based on this observation, the question is whether the biogas taskforce has the needed knowledge in order to support the biogas project being initiated. There is no question about the need for this support, but the question is if the biogas taskforce is not able of providing the need support.

4.3.2 Organic biogas plant to make standard

The suggestion from the organic farmers is for the biogas taskforce to help investigate, plan and build an organic biogas plant, which could function as a trail biogas plant for the organic agriculture and biogas industry. The biogas plant should be designed in a manner that makes it capable of handling the biomasses that are found in organic agriculture. A trail biogas plant could help increase the needed knowledge in the biogas taskforce, which could enable them of helping other biogas project in the development phase. The trail biogas plant would enable the taskforce in finding the problem area in the symbiosis between organic farmers and biogas plant, and hereby developing knowledge and support schemes that makes the symbiosis profitable. A trail biogas plant could also be used as a marketing scheme for the biogas taskforce and organic agriculture organizations, in order to show how biogas can be a part of organic agriculture, by supplying the organic farmers with the needed fertilizer.

4.3.3 Actions based on the Sjællandcase

The business case showed that three plant offers was capable of generating a profit, but that the profit for the farmers is at a level where they are expected to find it uninteresting. Therefore is it interesting to discuss how the farmers could find the symbiosis interesting. In earlier years the government gave a subsidy to the investment in biogas plants. This subsidy covered 30 percent of the plant investment, which would have an impact on the annual return of investment the investor would need in the business case. But using this subsidy meant that the subsidy to the produced energy could not be received. This was due to the fact that both subsidies were from EU funding, and a private company is only allowed to receive one subsidy from EU funding[32]. This meant that using the subsidy for plant investment, would decrease the earnings made from selling the produced energy. The subsidy for plant investment is not expected to return.

Another action that could be done by the government is to give a subsidy based on the amount of fertilizer that is produced from the biogas plant. Such a support scheme would make it more profitable for the biogas plants to focus on the fertilizer abilities in the degasified biomass, instead of now where this area is only given a small amount of focus. But the fear is that the biogas plants would focus more on the output of fertilizer than on the output of biogas, due to the production of fertilizer being more profitable. A subsidy to the degasified biomass will therefor need to be obligated, to that the production of biogas is maintained as high as now.

Another third possibility is for the government is to give subsidies to the transportation and handling of the biomasses, between the organic farmers and the biogas plant. As seen in the business case the costs within the symbiosis is the factor that are removing the profitability in symbiosis. Therefor would be interesting to investigate how much subsidies there should be given to the transportation and handling, in order to make the cooperation profitable.

4.3.4 Getting local acceptance

In the literature review, it was found that local acceptance of a biogas plant could be achieved by giving the local residence a degree of influence, or even ownership in the biogas project. But the fear by giving influence to the local residence is that the scoop of the biogas project is undermined, if the local residence has other objectives with a biogas project. If the residence is given too much influence it could harm the objectives from the biogas plant and organic farmers, removing the profitability in the symbiosis. But as it was found, a degree of influence is needed by the residents in order to achieve the acceptance. Following this, it is found important for the commissioning party to know what giving away this part of influence would have of effect on the objectives in the biogas project.

32 Conversation with Karen Jørgensen at VFL – Appendix 4 – Interviews/conversations

4.4 THE PROJECT APPROACH FROM VFL

The project approach located in VFL is not found to be the correct to use when developing a biogas project. This understanding is analyzed based on the fact that the technical knowledge from the plant manufactures is needed much earlier in the process, than where it is placed in the current process. The plant manufactures is needed early in the process, in order to calculate the output of biogas and fertilizer from the plant. The output is limited by the content of dry matte and nutrients the specific biogas plant is capable of processing. Therefore should this be known by VFL, in order to calculate the output of biogas and fertilizer from the biogas plant. Initially the perception was that letting the plant manufactures in early in the process would give them too much influence in the process, undermining the work and impartiality by VFL. But due to lacking knowledge, and the need to know the specifications from the plant manufactures, it is found that letting them in early would be preferable.

The plant manufactures should be used already after step 1.1, hereby getting the specifications of the biogas plants. The specifications could then be used to give a realistic estimation of the profitability in the symbiosis already in the phase 1. Letting the plant manufactures in early, would also give VFL the possibility to find the most suitable plant solutions already at an early stages. The best manufactures with the best solutions could then become partners throughout the project, with the object of optimizing the symbiosis by using their specific plant. By applying the interesting manufactures as partners to the biogas projects, would make them engaged in the project and give access to the needed knowledge from them.

4.5 RECOMMENDATIONS FROM THE INVESTIGATIONS

This section will summarize the recommendation found in the investigations throughout this project.

Recommendations		
Area	**Recommendation**	**Description**
Theoretical calculations	Determining biogas output	It is recommended that tests are performed, in order to analyze if the theoretical method can be found fully valid. The biomasses should be tested to get the need feed values, in order to calculate the theoretical output from the theoretical method. Meanwhile, should the same biomass be tested practically, in order to compare the results from the two tests. The comprising will show whether the theoretical method is valid, or if the method should be optimized.
	Determining fertilizer output	It is recommended that the conversion rate of organic nitrogen into ammonium is investigated further. There is found to be a lacking knowledge about the rate, and the impact the conversion has on the process. It is known that ammonium is inhibiting the process, but the maximum level of nitrogen content is unknown. Investigating this would enable the biogas plants in producing better fertilizer, at a profitable rate.

The symbiosis	Cost for transportation and handling	The cost for transporting and handling the biomasses, is found to have a massive impact on the profitability in the symbiosis. Although it was found in the Sjællandcase that the location of the plant only had a minor effect on the profitability, this area will have great possibilities for optimization.
	Loss of fertilizing ability	It is recommended that the loss of nutrients throughout the process flow in the symbiosis is investigated further. This should be done in order to find how much ability is lost, and how the loss can be prevented. This is found to have a massive impact on the profitability for the farmers in the symbiosis, and can therefor optimize the symbiosis.
	Optimal crop rotation	It is found that the optimal crop rotation in the symbiosis, is in counting the biogas and fertilizer production that can be generated from the biomasses, when planning the optimal crop rotation. The biogas plants ability to handle dry matter and nitrogen content, will make limitations to the biomasses, and hereby the crop rotation in the symbiosis. Therefor the biogas plants need inform the farmers, on the maximum dry matter and nitrogen content allowed in the plant.
	Technical solutions	It is recommended to investigate the use of the non-slurry based biogas plants further, due to these plants being the best performing solution, in to for fill the object in the Sjællandcase. These plants generated a small profit for the farmers, and it is therefore found interesting to optimize the symbiosis with a biogas plant using this technical solution.
	Distribution key	It is recommended to investigate the distribution key found in this project further. Both distribution keys found is working, but they are not considered to be optimal in relation to the Sjællandcase. Therefor will it be of great interest to investigate the use of these distribution keys in other biogas projects, in order to determine whether they are optimal for the distribution.
Synergy	Lacking knowledge	It is found as a hypothesis that the biogas taskforce is lacking knowledge, in order to support the development of biogas projects. It is recommended that this hypothesis is investigated, in order to clarify if this is the case. If there is lacking knowledge within the biogas taskforce, knowledge needs to be created.
	Development of knowledge	It is recommended, that the biogas taskforce, supports the development of an organic biogas plant, which are using the biomasses that are primarily found in organic agriculture. This support will enable the taskforce in developing knowledge that can be used in order to support other biogas projects. Also can such a plant be used in order to investigate relevant subjects in relation to the symbiosis, e.g. loss of nutrients.

	Subsidies to the symbiosis	It is recommended, that the possibilities for giving subsidies to the symbiosis are investigated further. It is found in this project, that an interesting way to give subsidies, is based on the amount of fertilizer produced from the degasification of biomasses. But it is also found, that this area needs further investigation, into the consequences of giving subsidies based on this.
VFLs approach	Earlier implementation of manufactures	It is found that the approach identified, can be used in order to calculate the profitability in a business case. It is although found that the plant manufactures should be implemented in the process much earlier, than found in the approach. The manufactures should already be implemented in the first loop.

5. CONCLUSION AND FURTHER WORK

This phase will be divided into three sections. This first will contain the reflection to the project, and the methods used in order to conduct the project. The second sections will be the overall conclusion to the project. The third and last section will contain a short conclusion for each of the stakeholders, and the further work proposed.

5.1 REFLECTIONS

This section will present the reflections that have been considered regarding the result and findings from this project. The reflections are presented in the following in an unstructured manner.

- The calculations and conclusion on whether a symbiosis between organic farmers and a biogas plant is profitable, is conducted only based on one case study. Therefor is it found, that the result could be otherwise, if a different case study was to be used. It is although expected that a result would be similar, due to the hypothesis found in VFL, and the fact that only one organic biogas plant is operating in Denmark. Another fact, that supports this presumption, is the low influence from the transportation cost on the total profit. But this presumption is not leading to a conclusion, that this will be the case for all biogas projects, further investigations is needed in order to come up with that conclusion.

- Through the case study, it was found that the organic farmers in the Sjællandcase would only participate in the symbiosis, with the precondition that their crop rotation could stay as it currently is. It is although found, based on the knowledge gathered in this research, that it could be interesting for the farmers to change their rotation. This would mean implementing a larger amount of the biomasses that are profitable for the symbiosis. The project shows that biomasses such as yellow mustard and regrown seed grass, is not contributing with a lot of profit to the symbiosis, and is therefore not optimal in the crop rotation, in relation to the output of biogas and fertilizer.

- In relation to foregoing reflection, the use of the degasified biomass as fertilizer in the crop rotation is found. The yield response is found based on the crops in the farmer's current crop rotation in the Sjællandcase. The question is if other crops will give a better yield response, than the ones found in the current rotation. This is although not expected, due to the crops in the current crop rotation being rated as the most profitable for organic farmers.

- The delimitations to the project stated, that only the sale option of selling the biogas as electricity was used in this project. This was selected in order to compare the plant manufactures from similar conditions. But it would be interesting to know, if the result of the symbiosis will be the same, if the other sales options was available. This is although not expected, due to previous investigations showing similar or worse economy in the symbiosis.

- The approach proposed on how VFL should development of biogas projects, is only based on knowledge found from persons that have not be conducting all phases of a biogas project. Therefor can it be questioned whether the approach would be functioning in reality. Also is the approach only analysed based on the single case study that is used in this project. It would be appropriate to implement the suggested change, and do more trails with the approach, before making a final conclusion to the approach.

- The validity and reliability of the findings are overall found to be good. This is due to the constant verification that has been conducted in the project. Although is verification of the specific plant offers from the manufactures hard to conduct, due to lacking knowledge of the specific plant solution. But the validity is still found to be high, due to the fact that the plant manufactures is interested in investigating if their plant solution is interesting for organic agriculture.

- Only some of the plant manufactures that was presented with the material from the Sjællandcase, returned with a plant offer. Therefor is only the received plant offers included in the business case. The question is whether there are biogas plants that are better in solving the object of this project, than the plant offers received. The plant manufactures is found based on experience from VFL, and the manufactures approached is therefor expected to be ones that are most possible of solving the object.

5.2 CONCLUSION

The object for this thesis was to answer the following main research question;

"Can organic biogas become mutually profitable for organic farmers and for commercial biogas suppliers in Denmark?"

The answering of the research question was done based on a case study, with three farmers located in the west of Sjælland. The case was found in the overall project from VFL, where the object of using the case study, is to analyze the possibilities in giving the organic farmers access to a greater amount of fertilizer, through interaction with a biogas plant. The case study was used, in order to find the objectives and preconditions to the biogas project, proposed by the three farmers in the case study. The objectives and preconditions from the case studies were used, in order to make a framework for the business case, and in order to find the important areas in the symbiosis. In order to investigate the areas that needed further investigations, an organic biogas workshop was attended by the researcher. The workshop gave the researcher possibility to investigate the symbiosis and synergy further, hereby determining the important factors in the symbiosis. These factors would need to be handled in order to be able of calculating the business case, which could show profitability in the symbiosis. The case study and workshop enabled the researcher in defining the symbiosis and synergy, through mapping of the cooperation. In relation to this was an approach proposed, on how VFL would develop a biogas project, in order to come up with a business case. This was done in order to determine how the business case should be structured, based on the findings form the case study. The mapping of the symbiosis, and the areas found to need further investigation, was used in the literature study in order to find the appropriate literature. Literature was found in order to calculate the profitability in the symbiosis, and to discuss the issues that have effect on the profitability. In order to verify the findings from the literature review, a retroductive synthesis was conducted. The retroductive synthesis was used in order to gather, analyze and validate, the literature needed in order to conduct the business case. This also included gathering plant offers from plant manufactures, which would enable the researcher in answering the research question. The business case showed that only a low degree of profitability was found, in the symbiosis between the biogas plants and the three farmers, in the case study. The reason for this was discussed in the following discussion, where all the main findings from the project were discussed.

It was found in the case study, and the workshop, that investors are needed for the biogas plant in the symbiosis. The investors want an annual return of investment of minimum ten percent, when investing in a biogas plant. Based on this being a precondition to the existence of the symbiosis, is the cooperation found profitable for the biogas plant, due to the annual return of investment of ten percent. The return of investment is found to be valid, due to the level of risk the investors are having when investing in a biogas plant. The business case was calculated with this precondition. The business case showed that the symbiosis was capable of generating a small profit for the farmers, with the optimal conditions as the condition. If there is no option for selling the bi-produced heat, and there is a loss in fertilizer ability of 20 percent, is there found no profitability in the cooperation. It is estimated that the scenario with no heat sale and a loss in fertilizer ability, is the most realistic scenario. Therefor is it found that with the precondition, ensuring the investor ten percent annual return of the investment, is there no profitability in the symbiosis. It is also found that the profitability is not much better when lowering the annual return of investment. It is found that the great costs in the symbiosis is related to the transportation and handling of the biomasses. Without the influence of these costs is the symbiosis found to be profitable, but the cost related to the symbiosis is inevitable. It is therefore concluded that subsidies is needed in order to make the symbiosis profitable for both parties.

There is found to be synergy between the goal stated in the Danish national policies, and the objective in the symbiosis between a biogas plant and organic farmers. This is especially found due to the existence of the biogas taskforce, in the government. This organization is set up in order to get more biogas plant constructed in Denmark. But it is found that the taskforce and government in general, is not capable of supporting the biogas projects being initiated. There is a great need for construction of an organic biogas plant, using the primarily biomasses from organic farming. Such a plant would enable the taskforce and the organic farmers in developing the needed knowledge, in order to get more organic biogas plants constructed. It is highly questionable, if the goal for doubling the area with organic farming before 2020 can be reached, based on the current legislations, if not organic biogas production is implemented in organic farming.

5.3 STAKEHOLDER CONCLUSION AND FURTHER WORK

This section will shortly describe the conclusions for each of the stakeholder, as it is found from the researcher. This will also include the proposed further work from

Organic farmers

The research has shown that organic biogas plants will give access to a larger amount of organic fertilizer, but that there is no profitability found in the cooperation with a biogas plant. The aim for the organic farmers from this research is to optimize the symbiosis, which could be done through conducting additional case studies and business cases, hereby finding the problem area that needs solving. Also is it interesting for the farmers to investigate the possibilities for a support scheme, which hereby could make the symbiosis profitable.

Biogas plant and plant manufactures

The biogas plant, and hereby investors, it is found that the symbiosis is profitable, if it is a precondition that an annual return of investment is secured. But as long as the symbiosis is not profitable for the other party, the symbiosis cannot exist. Therefore is it interesting for the biogas plants to optimize their operation, with the aim of being more suitable to the demands from the organic farmers. This could be done by lowering the loss there is when converting the biogas into electricity, hereby creating better earnings for the symbiosis. Another aspect that could, or even should be addressed, is the biogas plants ability to handle nitrogen, and convert it into ammonium nitrogen. By improving these areas will the biogas plant be able of generating a higher profit, which should enable the symbiosis, and higher return of investment for the investors.

The symbiosis
The symbiosis is not found profitable due to the great costs that are related with the symbiosis. The future work proposed within the symbiosis, is to optimize the operation. The optimization should be done in relation with the organic farmers, due to their crop and field selection having great influence on the cost in the symbiosis. This will also including optimization of the location for a biogas plant. Another possible way the symbiosis can be optimized, is through a payment scheme internally in the symbiosis. This has not been investigated in the thesis, due to a precondition from the farmers being, that the crops should not compete with the current high earning crops.

National political interest
A great level of synergy is found between the coals stated in the national policies, but a lacking level of knowledge is found, hereby enabling the biogas taskforce in achieving the stated goals. The future work from the governmental institutions, is proposed to focus on developing the needed knowledge in order to help the biogas project being completed. The first aim would be to find what knowledge is needed, in order to support the biogas project. Hereafter should the needed knowledge be created through the development, construction and operation of an organic biogas plant. Another objective should be to investigate the possibilities of giving a subsidy to the organic biogas plants, which will make the symbiosis profitable for both biogas plant and the organic farmers.

VFL
The object of the overall project is answered through this project. Biogas plants can be one of the solutions, which make more organic fertilizer available in organic farming. But the hypothesis stated by VFL, is still found to be true. This project has increased the understanding of this area with in VFL, and the project has therefor achieved the objectives for VFL. Their future approach should be on finding the right development path for the symbiosis, in order to make it profitable for the involved parties. This will mean supporting all other stakeholders in their future tasks, toward finding profitability in the symbiosis. Also is it suggested, that further case studies and business cases is conducted, in order to find more knowledge on the barriers to the symbiosis.

Universities and knowledge centers
This thesis has shown that there are great possibilities with in the symbiosis, but that profitability is needed to be found, in order for the symbiosis to become a reality. Therefor is this subject found as highly interesting for universities and knowledge centers, with the object of finding the missing solution to the problem.

6. BIBLIOGRAPHY

Adam, D. (2001). Nutritionists question study of organic food.
Agro tech. (2007). *Farm test - Transport af gylle.* Agro tech.
Andersen, W. S. (2011). *Production economy - Organic.* Aarhus: Knowledge centre for Agriculture.
Angelidaki, I., Alves, M., Bolzonella, D., Borzacconi, L., Campos, J. L., Guwy, A. J., et al. (2009). Defining the biomethane potential (BMP) of solid organic wastes and energy crops: a proposed protocol for batch assays. *Water science & technology*.
Artanti, D., Saputro, R. R., & Budiyono, B. (2012). Biogas Production from Cow Manure. *International Journal of Renewable Energy Development*.
Askegaard, M., & Eriksen, J. (2007). Growth of legume and nonlegume catch crops and residual-N effects in spring barley on coarse sand. *J. Plant Nutr. Sci.*
Biao, X., Xiaorong, W., Zhuhong, D., & Yaping, Y. (2002). Critical impact assessment of organic agriculture . *Journal of Agriculture and Environmental Ethics*.
Bioenarea. (2011). *The Bioenergy System Planners Handbook*. Hentede 1. April 2014 fra Bioenarea - Improvw regional policies for bio-energy and teritorial development: http://bisyplan.bioenarea.eu/html-files-en/03-02.html
Biogas Taskforce. (2013). *BUSINESS CASE FOR BIOGASANLÆG MED AFSÆTNING TIL NATURGASNETTET.* Biogas Taskforce.
Birkmose, T., Hjort-Gregersen, K., & Stefanek, K. (2013). *Biomasse til biogasanlæg i Danmark.* Aarhus: Agritech.
Blaikie, N. (2010). *Designing Social Research.*
Buranov, A. U., & Mazza, G. (2008). Lignin in straw of herbaceous crops. *Industrial crops and products*.
Chen, Y., Cheng, J. J., & Creamer, K. S. (2007). Inhibition of anaerobic digestion process: A review. *Bioresource technology*.
Cherr, C. M., Scholberg, J. M., & McSorley, R. (2006). Green Manure Approach tp Crop Production - A Synthesis. *American Society of Agronomy* .
Cirman, A., Domadenik, P., Koman, M., & Redek, T. (2009). The kyoto protocol in a global perspective. *Economic and business review*.
Cobb, D., Feber, R., Hopkins, A., Stockdale, L., O'Riordan, T., Firbank, L., et al. (1999). Intregrating the environmental and economic consequences of converting to organic agriculture: Evidence from a case study.
Copenhagen Economics. (2012). *Bioøkonomiens potentiale og værdi for landdistrikterne.* Fødevareministeriet.
Creswell, J. W. (2009). *Research design.* SAGE.
Danish Commission on Climate Change . (2011). *Energy strategy 2050 - From coal, oil and gas to green energy.* The Danish Goverment.
Dansk Gasteknisk Center a/s. (2009). *Biogas til nettet.* Hørsholm: Dansk Gasteknisk Center a/s.
Darsøe, L. (2011). *Innovationspædagogik.*
David, C., Jeuffroy, M., Laurent, F., Mangin, M., & Meynard, J. (2004). The assessment of Azodyn-Org model for managing nitrogen fertilization of organic winter wheat. *European journal of agronomy*.
Deloitte. (2013). *Afdækning af muligheder for at fremme investeringer i biogas - Status muligheder og betingelser i forbindelse med finansiering af biogasanlæg.* Deloitte.
DLBR. (2000). *Kvælstof - et nærringsstof og et miljøproblem.* DLBR.
DLBR. (2005). *Prisen på halm til kraftvarme?* Februar.
DLBR. (2006). Udbytte- og dyrkningssikkerhed ved et varieret sædskifte i forhold til et ensidigt sædskifte. *Plantekongres 2006 - Driftsledelse*.

DLBR. (2008). *Pas på fosfor - Gør ikke et vigtigt næringsstof til et miljøproblem.* Ringkøbing: Ringkøbing Amt.
DLBR. (2008). *Økonomien ved etablering og drift af biogasanlæg.* DLBR.
DLBR. (1. November 2013). *Maskinomkostninger Gødskning 2014*. Hentede 1. April 2014 fra Farmtal Online: https://farmtalonline.dlbr.dk/Grid/uiGrid.aspx?Farmtal=11636&ViewType=View&Start=01-01-2014&Slut=01-01-2014
DLBR. (1. November 2013). *Maskinomkostninger Høst 2014*. Hentede 1. April 2014 fra Farmtal Online: https://farmtalonline.dlbr.dk/Grid/uiGrid.aspx?Farmtal=11656&ViewType=View&Start=01-01-2014&Slut=01-01-2014
DLBR. (1. April 2014). *Prognose salgspriser for økologisk planteprodukter*. Hentede 1. April 2014 fra Farmtal online: https://farmtalonline.dlbr.dk/Grid/uiGrid.aspx?Farmtal=15&ViewType=View&Start=01-01-2012&Slut=01-10-2014
DLBR Economy. (2011). *Business check cropproduction 2011 - Conventional and organic sales crop.* Aarhus: DLBR.
DLBR Økonomi. (2011). *Business Check planteproduktion 20011.* DLBR.
Eggert, H. (2011). *Maximising biogas production efficiency.* February .
Elzen, M. d., Höhne, N., & Vliet, J. v. (2009). Analysing comparable greenhouse gas mitigation efforts for Annex I countries. *Energy polocy*.
Energi styrelsen. (2010). *Anvendelse af biogasressourcerne og gasstrategi herfor.* Energi styrelsen.
Energi styrelsen. (2011). *The second national action plan on energy efficiency under directive 2006/32/EF.* Energi styrelsen.
Energi styrelsen. (2012). *Biogas taskforce arbejdsplan.* Energi styrelsen.
Energinet.dk. (2013). *Regler for tilførsel af opgraderet Biogas til det Danske Gassystem.* Energinet.dk.
Energistyrelsen. (2014, February 14). *Energistyrelsen - Presse*. Retrieved February 14, 2014, from http://www.ens.dk/info/nyheder/nyhedsarkiv/statsstoetten-biogas-afklaret-kommissionen
Energistyrelsen. (2014). *Energiscenarier from mod 2020, 2035 og 2050.* Energistyrelsen.
Energy Efficiency Watch. (2013). *Energy efficiency in Europe - Assessment of Energy Efficiency Action Plans and policies in EU Member states 2013 - Denmark.* Energy efficiency watch.
Esposito, G., Frunzo, L., Liotta, F., Panico, A., & Pirozzi, F. (2012). Bio-Methane Potential Tests To Measure The Biogas Production From The Digestion and Co-Digestion of Complex Organic Substrates. *The Open Environmental Engineering Journal*.
European comission. (2008). *Til kamp mod klimaændringer - EU fører an.* Europa Kommissionen.
European Comission. (2011). *National Energy Efficiency Action Plans (NEEAPs) - Update on implementation.* European comission.
Fageria, N. K., & Baligar, V. C. (2005). Enhancing Nitrogen Use Efficiency in Crop Plants. *Advances in Agronomy,*.
Foissy, D., & Vian, J.-F. (2014). Managing nutrient in organic farming system: reliance on livestock production for nutrient management of arable farmland. *Organic Agriculture*.
Guba, E. G. (1990). *The paradigm dialog.*
Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research.
Hansen, K. H., Angelidaki, I., & Ahring, B. K. (1998). ANAEROBIC DIGESTION OF SWINE MANURE: INHIBITION BY AMMONIA.

Hellström, M. (1998). *Vindkraft i harmoni.*
Hepperly, P., Lotter, D., Ulsh, C. Z., Seidel, R., & Reider, C. (2009). Compost, Manure and Synthetic Fertilizer Influence Crop Yeilds, Soil Properties, Nitrate Leaching and Crop Nutrient Content. *Compost Science & Utilization*.
Holm-Nielsen, J. B., Seadi, T., & Oleskowicz-Popiel, P. (2009). The future of anaerobic degestion and biogas utilization. *Bioresource technology*.
IFOAM. (2012). *The IFOAM norms for organic production and processing.*
IFOAM. (2014). *Principper for økologisk jordbrug.*
Innovationsnetværket for Biomasse. (2010). *Kogebog for etablering af biogasanlæg.* Agro business park / Innovationsnetværket for Biomasse.
Jobert, A., Laborgne, P., & Mimler, S. (2007). Local acceptance of wind energy: Factors of succes identified in French and German case studies. *Energy Policy*.
Jørgensen, P. J. (2009). *Biogas - Green Energy.* Aarhus University.
Jørgensen, T. V. (2012). Organisering af høst og afsætning af biomasse fra engarealer. *Anvendelse af biomasse fra engarealer*.
Jørgensen, U., Elsgaard, L., Sørensen, P., Olsen, P., Vinther, F. P., Kristensen, E. F., et al. (2013). *Biomasseudnyttelse i Danmark - Potentielle ressourcer og bæredygtighed.* Aarhus: Aarhus Universitet.
KAUFHOLZ, H. (15. January 2014). *Politiken*. Hentede 17. February 2014 fra Politiken økonomi: http://politiken.dk/oekonomi/virksomheder/ECE2182258/boelge-af-maelkeboender-opgiver-oekologien/
Kim, J., Park, C., Kim, T., Lee, M., Kim, S., Kim, S. W., et al. (2003). Effects of various pretreatments for enhanced anaerobic digestion with waste activated sludge. *Journal of Bioscience and Bioengineering 95*.
Kim, M., Gomec, C., Ahn, Y., & Speece, R. E. (2003). Hydrolysis and acidogenesis of particulate organic material in mesophilic and thermophilic anaerobic digestion. *Environmental Technology*.
Kirchmann, H. (1985). *Losses, plant uptake and utilization of manure nitrogen during a production cycle .*
Knowledge Centre for Agriculture. (2. June 2009). *Kalium til økologiske afgrøder*. Hentede 22. May 2014 fra Knowledge Centre for Agriculture: https://www.landbrugsinfo.dk/Oekologi/Planteavl/Afgroeder/Korn/Sider/Kalium_til_oekologiske_afgroeder.aspx
Knowledge Centre for Agriculture. (2010). *Økonomi ved grovfoderlagre.* Knowledge Centre for Agriculture.
Knowledge Centre for Agriculture. (07. 12 2011). *Knowledge Centre for Agriculture*. Hentede 24. 04 2014 fra Landbrug Info: https://www.landbrugsinfo.dk/Energi/Biogas/Sider/Kvaelstofudnyttelsen_af_afgasset_gylle.aspx
Knowledge Centre for Agriculture. (26. 04 2012). *Landbrug Info*. Hentede 24. 04 2014 fra Knowledge Centre for Agriculture: https://www.landbrugsinfo.dk/Oekologi/Planteavl/Goedskning/Sider/leo_120426_kvaelstofrespons.aspx
Knowledge Centre for Agriculture. (12. 04 2012). *Økologiske sædskifter med biomasse*. Hentede 25. 04 2014 fra Landbrug Info : https://www.landbrugsinfo.dk/Oekologi/biogas/Sider/Oekologiske_saedskifter_med_biomasse.aspx
Knowledge Centre for Agriculture. (06. 05 2013). *Brug gødningen så den får større værdi*. Hentede 24. 04 2014 fra Landbrug Info: https://www.landbrugsinfo.dk/oekologi/planteavl/goedskning/sider/leo_120426_kvaelstofrespons.aspx

Knowledge Centre for Agriculture. (1. November 2013). *Maskinomkostninger Høst 2014.* Hentede 6. May 2014 fra Farmtal.dk: https://farmtalonline.dlbr.dk/Grid/uiGrid.aspx?Farmtal=11656&ViewType=View&Start=01-01-2014&Slut=01-01-2014

Knowledge centre for Agriculture. (2013). *Mød Videncentret.* Aarhus: Videncentret for landbrug.

Knowledge centre for Agriculture. (2013). *Organic Farming at The Knowledge centre for Agriculture.* Aarhus: Knowledge centre for Agriculture.

Knowledge Centre for Agriculture. (01. January 2014). *Dyrkningsvejledning, Biomasse til økologisk biogasproduktion.* Hentede 5. April 2014 fra Knowledge Centre for Agriculture: http://dyrk.plant.dlbr.dk/web/Forms/vejledning.aspx?editorMode=false&cropID=227

Knowledge centre for Agriculture. (17. February 2014). *Knowledge centre for Agriculture*. Hentede 17. February 2014 fra vfl.dk: http://www.vfl.dk/Om_VFL/OmVidencentretforlandbrug.htm?WBCMODE=PresentationUnpublished%3bshowmenu%3fMode

Knowledge centre of Agriculture . (17. February 2014). *Knowledge centre of Agriculture* . Hentede 17. February 2014 fra vfl.dk: http://www.vfl.dk/Afdelinger/Planteproduktion/Organisation/Bioenergi/OplaegOgForedrag.htm?WBCMODE=PresentationUnpublished%3bshowmenu%3fMode

Knowledge centre of Agriculture. (17. February 2014). *Knowledge centre of Agriculture*. Hentede 17. February 2014 fra vfl.dk: http://www.vfl.dk/Afdelinger/Oekologi/OmOekologi/OmOekologi.htm?wbc_purpose=iikulcbzn

Konwledge centre for Agriculture . (17. February 2014). *Konwledge centre for Agriculture* . Hentede 2014. February 2014 fra vfl.dk: http://www.vfl.dk/Om_VFL/Missionvisionogvaerdier/missionvisionvaerdier.htm?WBCMODE=PresentationUnpublished%3bshowmenu%3fMode

Labatut, R., Angenent, L., & Scott, N. (2010). Biochemical methane potential and biodegradability of complex organic substrates. *Bioresource technology*.

Ladatut, R. A. (2012). *ANAEROBIC BIODEGRADABILITY OF COMPLEX SUBSTRATES: PERFORMANCE AND STABILITY AT MESOPHILIC AND THERMOPHILIC CONDITIONS.* Faculty of the Graduate School of Cornell University .

Ladha, J., Pathak, H., Krupnik, T., Six, J., & Kessel, C. v. (2005). Efficiency of fertilizer nitrogen in cereal production: Retrospects and prospects. *Advances in Agronomy,*.

lanbrugsrådgivning, D. (2009). *økologisk biogas - Hvorfor og hvordan.* Dansk lanbrugsrådgivning.

Larsen, S. U., & Maegaard, E. (2010). *Følsomhedsanalyser for driftsøkonomi ved dyrkning af energipil.* Vindencentret for landbrug and AgroTech.

Leeuwenhoek, A. v. (1995). Guest editorial.

Lesteur, M., Latrille, E., Maurel, V. B., Roger, J. M., Gonzalez, C., Junqua, G., et al. (2010). First step towards a fast analytical method for the determination of Biochemical Methane Potential of solid wastes by near infrared spectroscopy. *Bioresource technology*.

Ludington, D. (2010). *Calculating the heating value of biogas.*

Mattocks, R. (2002). Understanding biogas. *Countryside and Small Stock Journal*.

Miljøministeriet - Miljøstyrelsen. (2003). *Basisdokumentation for biogaspotentialet i organisk dagrenovation*. Hentede 15. May 2014 fra Miljøministeriet - Miljøstyrelsen: http://www2.mst.dk/common/Udgivramme/Frame.asp?http://www2.mst.dk/Udgiv/publikationer/2003/87-7972-590-2/html/default.htm

Miljøministeriet - Miljøstyrelsen. (31. July 2008). *Introduktion til standardvilkår for K 213-virksomheder.* Hentede 8. May 2014 fra Miljøministeriet - Miljøstyrelsen: http://mst.dk/media/mst/68080/udkast%20læsevejlening%20julii%202008.pdf

Miljøministeriet Naturstyrelsen. (2014). *VVM trin for trin*. Hentede 8. May 2014 fra Miljøministeriet Naturstyrelsen: http://naturstyrelsen.dk/planlaegning/miljoevurdering-og-vvm/vvm/hvad-er-vvm/vvm-trin-for-trin/

Miljøstyrelsen. (2003 2003). *Basis dokumentation for biogaspotentialet i organisk dagrenovation.* Hentede 5. Maj 2014 fra Miljøprojekt nr. 802, 2003: http://www2.mst.dk/common/Udgivramme/Frame.asp?http://www2.mst.dk/udgiv/publikationer/2003/87-7972-590-2/html/bilag03/kap02.htm

Ministeriet for Fødevare, Landbrug og Fiskeri. (2014). *Vejledning om økologisk jordbrugsproduktion.* Ministeriet for Fødevare, Landbrug og Fiskeri.

Ministeriet for Fødevarer, Landbrug og Fiskeri. (2011). *Statistics on organic farms 2011.* Ministeriet for Fødevarer, Landbrug og Fiskeri.

Ministeriet for Fødevarer, Landbrug og Fiskeri. (2014). *Vejledning om økologisk jordbrugsproduktion.* NaturErhvervstyrelsen.

Ministry of Food, Agriculture and Fisheries. (2013). *Vejledning om gødskning- og harmoniregler.* Ministry of Food, Agriculture and Fisheries.

Molinuevo-Salces, B., Larsen, S. U., & Ahring, B. K. (2013). Biogas production from catch crops: Evaluation of biomass yield and methane potential of catch crops in organic crop rotations. *Biomass and bioenergy*.

Morgan, J. (March 2014). *6 Functions for the International climate Agreement*. Hentede 15. April 2014 fra World resources institute: http://www.wri.org/blog/2014/03/6-functions-international-climate-agreement

Muller, A. (2009). Sustianable agriculture and the production of biomass for energy use. *Climate Change*.

Mæng, H., Lund, H., & Hvelplund, F. (1999). Biogas plants in Denmark: technological and economic developments. *Applied energy*.

Møller, H. B. (December 2006). Kvælstofomsætning i biogasanlæg. *Forskning i Bioenergi NR. 17*.

NaturErhvervstyrelsen. (3. June 2014). *Økologistatistikken for 2013: det økologisk areal går tilbage*. Hentede 10. June 2014 fra Ministeriet for Fødevarer, Landbrug og Fiskeri: http://naturerhverv.dk/servicemenu/nyheder-og-presse/nyheder/nyhed/nyhed/oekologistatistikken-for-2013-det-oekologiske-areal-gaar-tilbage/

Neill, C. (2011). Impacts of crop residue management on soil organic matter stocks: A modelling study. *Ecological Modelling*.

Nielsen, W. (2003). *Teknik til halmbjærgning siden midten af det forrige århundrede.* Horsens: Danmarks JordbrugsForskning, Afdelingen for Jordbrugsteknik, Forskningscenter Bygholm .

Oberthür, S., & Ott, H. E. (1999). *The Kyoto Protocol - International Climate Policy for the 21st Century.*

Oelofse, M., Jensen, L. S., & Magid, J. (2013). The implications of phasing out conventional nutrient supply.

Olesen, J. E., Askegaard, M., & Rasmussen, I. A. (2009). Winter cereal yields as affected by animal manure and green manure in organic arable farming. *European Journal of Agronomy*.

Olsen, L. E., Mejnertsen, P., & Askegaard, M. (2012). *Croprotation in organic crop production.* Aarhus: Knoeledge centre for Agriculture.

Petersen, J., & Sørensen, P. (2008). *Gødningsvirkning af kvælstof i husdyrgødning Grundlag for fastlæggelse af substitutionskrav.* Det Jordbrugsvidenskabelige Fakultet Aarhus Universitet.

Pham, C. H., Triolo, J. M., Cu, T. T., Pedersen, L., & Sommer, S. G. (2013). Validation and Recommendation of Methods to Measure Biogas Production Potential of Animal Manure. *Asian-Australasian Journal of Animal Sciences*.

Radwan, A., Sebak, H., Mitry, N. R., El-Zanati, E. A., & Hamad, M. (1993). Dry fermentation of agricultural residues. *Biomass and Bioenergy*.

Raju, C. S., Løkke, M. M., Sutaryo, S., Ward, A. J., & Møller, H. B. (2012). NIR Monitoring of Ammonia in Anaerobic Digesters Using a Diffuse Reflectance Probe. *Sensors*.

Santon, L. M., Michelon, P., Arenales, M. N., & Santos, R. H. (2008). Crop rotation scheduling with adjacency constraints.

Soland, M., Steimer, N., & Walter, G. (2013). Local acceptance of existing biogas plants in Switzerland. *Energy Policy*.

Sovacool, B. K., & Ratan, P. L. (2012). Conceptualizing the acceptance of wind and solar electricity. *Renewable and Sustainable energy reviews*.

Stevenson, F. K. (2001). A comparison of two methods to predict the landscape-scale variations of crop yield.

Svensson, L. M., Christensson, K., & Björnsson, L. (2005). Biogas production from crop residues on farm-scale level: is it economically feasible under conditions in Sweden? *Biopress Biosyst*.

Sørensen, P. (2012). Gødningsvirkning og håndtering af mobil grøngødning. *Kvælstofforsyning i økologisk planteavl*.

Sørensen, P., & Birkmose, T. (2002). *Kvælstofudvaskning efter gødskning med afgasset gylle.* Ministriet for Fødevare, Landbrug og Fiskeri.

Sørensen, P., Khan, A., Møller, H., & Thomsen, I. (2012). Effects of anaerobic digestion of organic manures on N turnover and N utilization. *Nitrogen Workshop 2012*.

Tanaka, S., & Kamiyama, K. (2002). Thermochemical pretreatment in the anaerobic digestion of waste activated sludge. *Water science and technology*.

The Danish Goverment. (2009). *Grøn vækst .* The Danish Goverment.

Thorup-Kristensen, K., & Dresbøll, D. B. (March 2010). Incorporation time of nitrogen catch crops influences the N effect for the succeeding crop. *Soil Use and Management*.

Triolo, J. M., Sommer, S. G., Møller, H. B., Weisbjerg, M. R., & Jiang, X. Y. (2011). A new algorithm to characterize biodegradability of biomass during anaerobic digestion: Influence of lignin concentration on methane production potential. *Biorecource technology*.

Triolo, J. M., Ward, A. J., Pedersen, L., Løkke, M. M., Qu, H., & Sommer, S. G. (2013). Near Infrared Reflectance Spectroscopy (NIRS) for rapid determination of biochemical methane potential of plant biomass. *Applied Energy*.

U.S. Department of Energy. (2014). *Mid-Atlantic clean energy application center*. Hentede 1. April 2014 fra U.S. Department of Energy: http://www.maceac.psu.edu/clean_energy_opportunity_fuels.html

Uffe Jørgensen, L. E. (2013). *Biomasseudnyttelse i Danmark - Potentielle ressourcer og bæredygtighed.* Aarhus Universitet.

United Nations . (1992). *United nation farmework convention on climate change.* United Nations.

United Nations. (1998). *KYOTO PROTOCOL TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE.* UNITED NATIONS.

Valentine, J., Clifton-Brown, J., Hastings, A., Robson, P., Allison, G., & Smith, P. (2012). Food vs. fuel: the use of land for lignocellulosic 'next generation' energy crops that

minimize competition with primary food production. *Global Cange Biology Bioenergy*.
Videncentret fo Landbrug. (2012). *Faktaark om fosfor (P).* Videncentret fo Landbrug.
Videncentret for landbrug. (20. January 2010). *Videncentret for landbrug*. Hentede 6. May 2014 fra Skal jeg køre gylle på vinter raps - eller investere i opbevaring? : https://www.landbrugsinfo.dk/Planteavl/Produktionsraadgivning-mark/Sider/pl_10_055.aspx
Videncentret for Landbrug. (2012). *Faktaark om Kalium (K).*
Walla, C., & Schneeberger, W. (2008). The optimal size of biogas plant. *Biomass and bioenergy*.
Ward, A. J., Hobbs, P. J., Holliman, P. J., & Jones, D. L. (2008). Optimisation of the anaerobic digestion of agricultural resources. *Bioresource Technology*.
Warren, C. R., & McFadyen, M. (2010). Dowa community ownership affect public attitude to wind energy? *Land use policy*.
Waste Management World. (1. Febraury 2013). *Dry anaerobic digestion biogas plant treating organic waste in California*. Hentede 1. April 2014 fra Waste Management World: http://www.waste-management-world.com/articles/2013/02/californian-biogas-plant-first-dry-anaerobic-digester-in-us.html
Watson, C., Atkinson, D., Gosling, P., Jackson, L., & Rayns, F. (2002). Managing soil fertility in organic farming systems. *Soil use and management*.
Woese, K., Lange, D., Boess, C., & Bögl, K. W. (1997). A Comparison of organically and conventionally grown foods.
Zafari, A., & Kianmehr, M. H. (2012). Management and reduction of chemical nitrogen consumption in Agriculture. *American journal of Plant Sciences*.
Zander, P., & Bachinger, J. (2006). *ROTOR, a tool for generating and evaluating crop rotations.* European Journal of Agronomy.
Öborn, I., Andrist-Rangel, Y., Askekaard, M., Grant, C. A., Eatson, C., & Edwards, A. C. (2005). Critical aspects of potassium management in agricultural systems. *Soil use and management*.
Økologisk Landsforening. (2012). *Håndborg i økologiske sædskifter - Økologisk dyrkning uden konventionel gødning.* Økologisk Landsforening.
Økologisk Landsforening. (2014). *Økologisk Landsforening - Aktionsplan for økologisk mælkeproduktion.* Økologisk Landsforening.