A nutrient and economic analysis of digestate processing in the region of Salland.

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Preface

This thesis is titled *A nutrient and economic analysis of digestate processing in the region of Salland*. I have written this thesis at the end phase of my master study Management Economics and Consumer studies.
Because of my agricultural background and my interest for related topics I ended up at the Business Economics group to work on a thesis with the topic digestate processing. Digestate processing is relatively new in The Netherlands so for me it was quite interesting to study about this. This topic was even more interesting because I had the opportunity to work on a real installation, Biogreen, with modern techniques. The times that I visited this installation were very nice and informative. I would like to thank Jan Schokker and Johan Veldhuis to provide me information on Biogreen. For me it was a surprise that quite interesting results came out of this study.
During the process of working on this thesis I have been very well stimulated by my supervisor Miranda Meuwissen. It was not always easy for me to stick to the topic and to be precise and consequent. Also writing in English formed a bottleneck but a good learning process for me. Via this way I would thank Miranda very much for her pleasant and motivating way of giving tips and comments regarding the content and the structure. Because Miranda was also supervising PhD student Solomie Gebrezgabher, who did part of her research about the same topic, we could help each other by exchanging information. I also would like to thank Solomie for the open way of cooperation.
I hope you will enjoy reading this thesis.

Doeko van't Westeinde

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Summary

Some regions in The Netherlands have to contend with a manure surplus. This means that because of the intensive livestock farming there is relatively more manure than land capacity (measured in nitrogen and phosphate). As a consequence farmers in these regions have to pay quite much money to transport it to other regions with more nutrient capacity. A possible solution for manure surpluses is to use it as a source of energy (manure fermentation) and to further process the ‘by products’ (digestate). Although much is known about the first aspect, i.e. manure fermentation, this does not hold at all for the second aspect i.e. the further processing of digestate.

In this context, the objectives of this project are: (1) to study the ‘digestate context’, such as the fermentation process, policy, the economics and comparable literature studies about processing bio products; and (2) to analyze nutrient and economic feasibility of using digestate or digestate products for a concrete plant. This plant concerns Biogreen in Heeten, Salland which processes manure by fermentating it, and which processes the digestate with different techniques as well. First a part of the digestate is separated and dried until 80% dry matter (d.m.) the rest is processed by ultra filtration and reverse osmosis. In removing their digestate and related products, Biogreen considers 3 regions, i.e. Salland, the municipality of Kampen and the Groninger Veenkoloniën, as well as the option of exporting products to Germany.

Digestate

The policy for the digestate as well as for the digestate products is the same as for the raw animal manure. However, the properties of digestate and Reverse Osmosis (RO) concentrate (an end product of Biogreen) are different from raw animal manure. Where nutrients in digestate are slightly better uptakable by plants, RO concentrate should become a substitute for artificial fertilizer with quite the same characteristics not only physically but also for the legislation. Compared with studies about manure fermentation very few studies have been done about the further processing of the digestate and making closed nutrient cycles with digestate or digestate products.

Biogreen

For Biogreen 4 scenarios have been evaluated: (i) unprocessed digestate; (ii) 80% d.m. digestate and liquid digestate; (iii) 80% d.m. digestate and RO concentrate as animal manure; and (iv) 80% d.m. digestate and RO concentrate as artificial fertilizer. Table I shows the results, which address the digestate and RO distribution across regions as well as cost and revenue aspects.

Looking at the distribution within The Netherlands Table I shows that for the first scenario, land capacity is needed in all 3 regions. This is because of the big amount of digestate. In the second scenario besides transport to Salland a little smaller part has to go to Kampen because of the smaller quantity and the lower N,P composition. The last 2 scenarios concern the same (low) amount. In this case Salland has enough capacity for the nutrients and also a lot of water is produced that can be expelled to the sewage.

For the revenues and cost balance all 4 profit margins are positive. All the revenues are the same except for the last scenario where RO concentrate will generate money because it is an artificial fertilizer substitute. Per scenario the margins increase because of the decreasing cost side. The quantities are getting smaller in the first 3 scenarios. So the removal cost decrease drastically. In scenario 4: 80% d.m. digestate

and RO concentrate as artificial fertilizer no removal cost have to be paid at all for RO concentrate, only transport.

All the scenarios turn out to be more positive compared with ‘doing nothing’ (no fermentation or digestate processing). When there is no interaction of Biogreen 55,350 tons manure have to be removed to 3 regions at costs of about € 1.3 million.

Changing circumstances with regard to fermentating manure

Three changing circumstances were studied for the Biogreen case, i.e. (i) without MEP subsidy; (ii) building on a new location; (iii) building on a new location with SDE subsidy. Table I shows the impact of these changing circumstances on profit margins. It can be seen that situation (i) has a big impact on the profit margins. This makes clear that subsidy is a very important revenue factor. Situation (ii) concerns building on an industrial location including new storage silos. These extra costs offer only 0.03 from the profitability compared to the previous situation. Situation (iii) concerns situation (ii) including SDE subsidy which is around 6 cent per kWh lower than the MEP subsidy. This results in quite lower profit margins and a negative margin for the ‘unprocessed digestate’ scenario.

Overall conclusions

- Subsidy plays a big role in this kind of industry. When receiving MEP subsidy all scenarios show positive profit margins. Without this subsidy only the scenarios where 80% d.m. digestate and RO concentrate as both animal manure and artificial fertilizer is produced show positive margins.
- Also with the current SDE[1] subsidy setting up new plants similar to Biogreen with ultra filtration and reverse osmosis seem to be profitable. In this situation only fermentation seems to be unprofitable.

[1] Successor MEP subsidy regulation since January 2008, energy subsidy per produced kWh electricity.

Table I *Digestate/RO concentrate distribution and cost/revenue balance for basis situation and changing circumstances per scenario*.

		Unprocessed digestate	80% d.m. digestate and liquid digestate	80% d.m. digestate and RO as animal manure	80% d.m. digestate and RO as artificial fertilizer
BASIS SITUATION	*x1,000 tons*				
Digestate/RO distribution					
Salland		26	27	10	10
Kampen		27	26	-	-
Veenkoloniën		8	-	-	
Germany (export)		-	8	8	8
Total		61	61	18	18
Revenues	*x € 1,000*				
Subsidy		1,509	1,509	1,509	1,509
Energy sales		1,306	1,306	1,306	1,306
Supply raw manure		775	775	775	775
Sales RO concentrate					50
Total revenues		**3,590**	**3,590**	**3,590**	**3,640**
Fixed cost					
Depreciation		450	510	660	660
Labor		72	80	84	84
Interest		95	107	139	139
Subtotal		*617*	*697*	*883*	*883*
Variable cost					
Transport		123	123	123	123
Supply co-products		413	413	413	413
Removal manure/ digestate/water/RO		1,094	950	209	59
Electricity		4	17	86	86
Maintenance		180	185	220	220
Subtotal		*1,814*	*1,688*	*1,051*	*901*
Total cost		**2,431**	**2,385**	**1,934**	**1,784**
Earnings before taxes		1,159	1,205	1,656	1,856
Profit margin		**0.32**	**0.34**	**0.46**	**0.51**
PROFIT MARGINS FOR CHANGING CIRCUMSTANCES					
Without MEP[1]		-0.17	-0.15	0.07	0.16
Building on new location		0.29	0.31	0.43	0.48
New with SDE[2] **subsidy**		-0.01	0.01	0.19	0.26

[1] Old subsidy regulation per produced kWh.
[2] New subsidy regulation per produced kWh.

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1 Introduction

1.1 Problem statement

In The Netherlands there are regions with a high concentration of livestock farming. Especially in a densely populated country like The Netherlands this high concentration of intensive agriculture has led to environmental problems as a consequence of an overproduction of manure. This manure surplus would not be a problem if there is enough land in the neighborhood to disperse it on (measured in nitrogen and phosphate amounts). So the overproduced nutrients have to be transported to other regions which is expensive.

A challenge in this is to breakdown this trend and create a cycle with neither overproduction of nutrients nor a lack of them. It might be possible to restore the cycle with technical solutions.

Besides of that for reasons of sharpening the usage norms for nitrogen dairy farmers see decrease their financial result with € 5-45 per hectare because of removing their surplus manure. On the other side arable farmers have to buy more artificial fertilizer and see their results decrease with € 5-35 per hectare as well (Van Dijk et al., 2006).

In this research such a technical solution concerns the further processing of digestate and can be a solution for struggling the manure surplus in a specific region.

Background

In the past studies have been done on nutrient cycles from manure fermentation. A study of Alterra made some environmental guidelines of bio fermentation installations. Looking at the nutrient flows of the inputs and outputs this study analyzed their sustainability (Zwart et al., 2006). Studies also concluded that it is not possible to close the cycle of nutrients when the nutrients of the digestate are determined as animal manure (for which the usage norms in most cases are lower) (Op ‘t Eynde, 2007). Mostly, studies with regard to this subject are done with the perspective of CO_2 reduction just like the study of Kuikman et al. (2000). However, their study claims that it is an advantage that the nutrients stay in the digestate and in this way this can be a possible substitute for artificial fertilizer. However, none of these studies with a regional view focuses on closing cycles with digestate.

Another way of getting rid of the digestate is exporting it to other countries. The advantage is that the nutrients balance in The Netherlands will be relieved. Also raw manure can be exported, but it has to fulfill some strict regulations like hygienisation (Boschloo, 2008).

Since the beginning of this century more bio fermentation installations have been built to make energy from manure. For reasons of producing green energy manure is becoming more and more interesting in The Netherlands. Moreover, the government recently decided to increase the subsidy for smaller bio fermentation installations which will stimulate the building of new ones (Anonymous, 2008a). The fermentated manure is a kind of ‘waste’ product. However, digestate is also a fertilizer with nutrients for plants. It may be possible that technical solutions can accelerate possibilities for digestate to bring it back on the land without negative consequences. An advantage of the digestate produced in bio fermentation installations is that the nutrients can be taken up easier by plants (Op ‘t Eynde, 2007).

1.2 Objectives and research questions

The objectives of this study are:

- *to review the 'digestate context' i.e. the fermentation process, policy, economics and region oriented studies with bio products*;
- *to analyse digestate scenarios for a given plant i.e. the distribution of digestate or digestate products and a cost/revenue analysis*.

These issues will be addressed for the data of a bio fermentation and digestate processing installation in Heeten, Salland where 50 pig farmers bring their manure together. All farmers live in a circle of 10 kilometres around the installation.
To be able to elaborate on these objectives properly some research questions have to be answered in advance:

- How is the bio fermentation process working?
- What are possible applications for digestate?
- What are the focus points of studies with a regional view?
- What are important subsidies with regard to bio fermentation installations?
- Which policy is relevant with regard to digestate?
- Which economical aspects are relevant with regard to digestate processing?
- Which regions are interesting for distribution of digestate (or manure)?

1.3 Outline of the report

In this report in chapter 2 a description of manure fermentation will be given. In this chapter also some background about policy, other literature studies and economical aspects of bio fermentation and digestate processing will be given. Chapter 3 concerns the materials and methods. In this part a description of the case in Salland will be given and the scenario analysis will be elaborated. Subsequently, the actual results of the study are described in chapter 4. At the end the report gives the conclusions, discussion and recommendations and recommendations for possible other studies.

2 From manure to digestate

This chapter will describe the process in which digestate is formed and how energy will become a result of that. Also the further processing of digestate will be described as well as the applications for it. Further, the policy concerning digestate will be reviewed and also an overview will be given of some region orientated studies with bio products.

2.1 Bio energy from fermentation

The way from manure to digestate shows some quite complex chemical steps. In short, digestate means fermentated manure. In most situations in The Netherlands digestate is the result (waste product) from making energy out of the raw animal manure. Due to the fermentation process a gas is produced which can be burnt to drive a generator that produces electricity. The fermentation process is driven by micro-organisms who convert organic material into biogas. Biogas consists mainly of methane gas (55-65%) and carbon dioxide (35-40%). Besides of these gasses also the corrosive gasses sulphur dioxide and ammonia are produced. These are filtered (SenterNovem, 2006).
In the fermentation process the temperature is an important issue. 3 levels of temperature are possible for fermentation: 0-20 degrees, 20-45 degrees and 45-75 degrees. The higher the temperature the more gas in a shorter period will be produced. In The Netherlands the temperature level of 20-45 degrees is most common (SenterNovem, 2008).

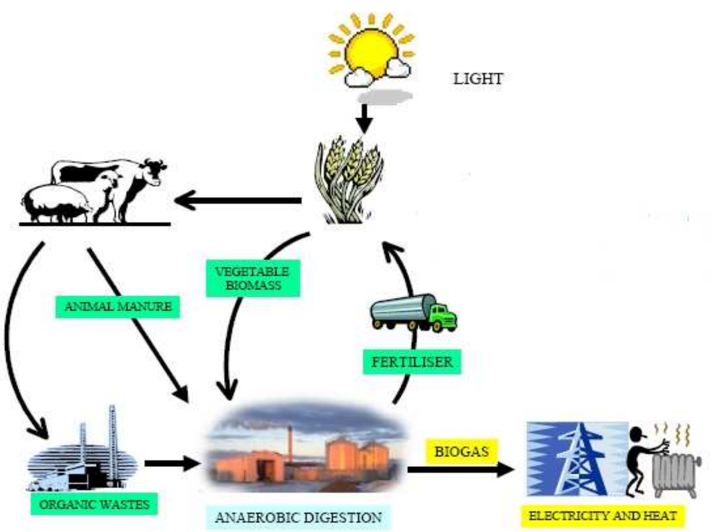

Figure 2.1. *Schematic overview of the bio-fermentation process and biogas production* (Makinemekanik, 2008).

The fermentation process in a bio fementation installation functions with absence of oxygen (anaerobic condition). The chemical steps which are made in a bio fermentation installation can be separated in 4 phases (Oudman, 2006).

1. Hydrolysis. The conversion of complex insoluble organic material in less complex dissolved organic material which will be taken up by bacteria.

2. Fermentation. The dissolved particles are converted by bacteria into simple acid bonds and alcoholics.
3. Acetogenesis. In this phase the fermentation products are converted into hydrogen, carbon acid and acetic acid.
4. Methanogenesis. In the last phase these acids are converted into methane gas and carbon dioxide.

In the fermentation process only the easy breakable organic particles are degraded. The organic particles which are difficult to degrade, like cellulose, stay in the digestate. In table 2.1 it is shown which factors are important for a good fermentation process which causes an as high as possible gas yield.

Table 2.1 *Important factors for fermentation processes* (Oudman, 2006).

Factor	**Explanation**	**Optimal situation**
Temperature	Higher temperatures accelerate the fermentation process	20-45 degrees most common
pH-value	1 general fermentation tank with different bacteria requires different pH-values. The bacteria who form the methane are most important to adjust the pH-value.	pH around 7,5
C/N relation	A balanced C/N ratio is necessary for a good fermentation progress	Around 10-30
Organic matter maximum	How much organic matter can be 'fed' without disturbing the bacteria.	Around 2 and 3 kg om/m^3
Duration	The time the manure is in the fermentation tank	25-40 days under standard temperature
Dry matter content	To keep everything mixable a maximum of dry matter is obliged	Around 15-20%
Particle size	The size of the particles determines their accessibility for micro-organisms	The smaller the better

To convert the produced biogas into electricity a heatpower installation is used. This exist of a gas engine to burn the gas and a generator to convert the heat into electricity. An average engine is able to produce 2,1 kWh electricity and 3,7 kWh heat from 1 m^3 gas. The engine converts 35-40 percent from the total amount of energy into electricity. The rest is high and low caloric heat. The high caloric heat coming from the exhausting fumes is regained and can be used to heat up the fermentation basin. The produced electricity can be used for own usage at the farm and the rest can be sold to the public net. The heat can also be used for the heating system in the stables and the living home or for further processing of the digestate (Oudman, 2006). Paragraph 2.2 will go about that.

Co-fermentation

In manure fermentation the fermentator itself is mostly the center of the installation. The fermentator is filled with fresh manure from the depot and often with other material for a good fermentation process. The fermentation of these extra products is called co-fermentation. In the fermentation process not all the manure and co-products are fermentated the residue is called the digestate. It is attractive to add a co-product because it increases the fermentation and more biogas is formed. Manure is a half digested product by animals so it is not fully optimal for producing as much gas as possible. The most common way of manure fermentation as described above is called wet-fermentation and is a continuous process. Another possibility is dry-fermentation. This takes places at only 1 place in The Netherlands and is not a continuous process (Westra, 2008).

For co-fermentation a number of products are allowed to add to the fermentator. Most agricultural crops are allowed and since 2005 the minister of agriculture added some other waste products from the potato industry to this list (Oudman, 2006). This is called the white list of allowed co-products. At test farm Nij Bosma Zathe some experiments with different co-products and their gas production have been done. Where pig manure only gives around 40 m^3 gas in combination with mais silage this is almost 5 times bigger and in combination with waste products from bakeries this is almost 17 times bigger see also figure 2.2 (Anonymous, 2008b).
In fermentation installations the manure that is used is most times liquid. Liquid manure is not only the most produced kind of manure it is also good to be fermentated. Products rich in straw stress the fermentation process when it consists of 40% straw at 35 degrees. At 55 degrees it stresses the fermentation process when a product contains 75% straw (Hashimoto, et al., 1983). The fermentation of straw becomes better when it is pretreated with a hydroxide solution (Hashimoto, et al., 1986).

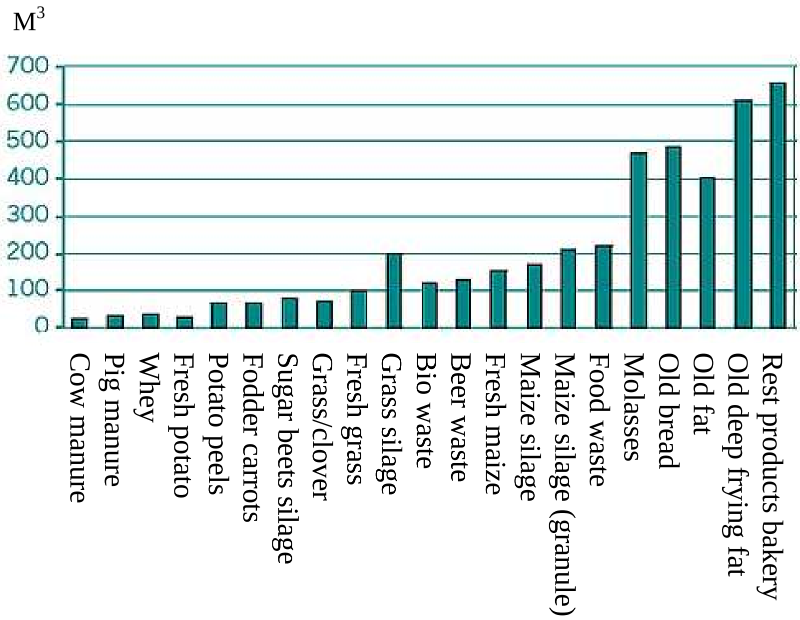

Figure 2.2 *Gas production per kg co-product in* m^3 (Anonymous, 2008b).

2.2 Application of digestate

As described above the main reason to invest in a fermentation installation is to produce energy out of the biogas. As the digestate is the left-over of this fermentation process this paragraph will describe some possibilities for the usage of digestate. The production of digestate is mostly seen as a waste flow where it is difficult to get rid of. This is especially the case in regions in The Netherlands with a surplus of manure. In regions without this problem enough land is available at the farm itself or in the direct neighborhood. However nowadays everywhere in the country a fee has to be paid to disperse manure and digestate as well on the fields. This paragraph makes clear that there are innovations to find solutions for the digestate.

2.2.1 Digestate as fertilizer

For the production of 1 kg N in artificial fertilizer 1.3 m^3 natural gas is necessary. Besides it is not CO_2 neutral. An disadvantage of the usage of organic fertilizer can be that part of the nitrogen is not direct available in the year of application. However, there are some predictors to determine the short-term availability. These are the content of $NH4^+$, the C:N ratio and the stability of the organic substances. Processing steps can influence these factors. Composting results in a low mineral N-content and a high organic matter stability, but a low C:N ratio. Anaerobic fermentation with digestate as a result reduces the C:N ratio and increases the stability of organic matter and the content of $NH4^+$ so it results in a product with a high content of directly available N (Gutser et al, 2005). The positive loaded $NH4^+$-ion will also bind easily to a clay-humus complex which is negative loaded. In this case the drainage of nitrogen via ground water will be limited (Op 't Eynde, 2006). The amount of nutrients (N,P,K) at the end of the fermentation is always the same as in the beginning situation. With co-fermentation the amount of nutrients of the raw manure increases with nutrients in the co-product. In digestate 50-80% of the nitrogen is in mineral form compared with 35-50% in raw manure. Precise fertilizing with digestate is easier for arable crops. However the N-P relation in digestate is not always optimal so that it is necessary to add artificial nitrogen for the best crop results. An advantage of digestate is that it is more homogeneous and constant than raw manure. It also contains less weed seeds and less pathogens. The effect for the soil is the same as raw manure because of the fact that cellulose has not been broken down which causes a good organic matter structure (Oudman, 2006).

Liquid and solid separation

It is also possible to separate the digestate in a solid and liquid part. The separation is possible via mechanically separation like a manure latch or a decanter and chemical separation with for example different kinds of filters (SenterNovem, 2007). The solid part contains most of the phosphate, the liquid part most of the nitrogen (Oudman, 2006). The content of potassium stays the same after separation and can only be filtered out via adding a chemical bonding liquid. When talking about the solid part it is not completely solid. The dry matter content depends on the technique which is used, but it fluctuates between 40 and 90 percent (Melse et al., 2004).

The usage of this liquid part with nitrogen is attractive because the nitrogen can be bonded to the clay-humus complex in its ammonium phase by its positive charge. This makes it less mobile by groundwater than the negative charge of the nitrate form which is also uptakable by plants. Because of this change to a more mineral form by the fermentation process fertilizing with digestate can be compared with artificial fertilizing with the difference that the production of the last one is very unsustainable (Op 't Eynde, 2006).

It is also possible to denitrificate the liquid part so that it fulfills the regulation of the body of surveyors of the dikes and can be expelled to the sewage or surface water (SenterNovem, 2007).

The choice which system to use for separation the digestate depends on the purpose of the owner. When the purpose is to separate the phosphate content efficiently a decanter is most ideal. When the purpose is to create a clear liquid to expel a mechanical and some chemical filters are necessary (Melse et al., 2004).

Ultra-filtration and reverse osmosis
A step after the mechanical separation of the digestate is to process further the liquid part via ultra-filtration and reverse osmosis. The end result is a clear colored liquid which can be expelled or used to clean the stables or trucks (Melse et al., 2004).
An schematic overview of both processes is to be seen in figure 2.3. During both processes a concentrate is formed.

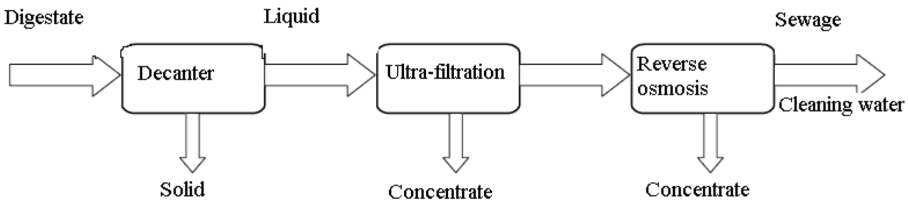

Figure 2.3. *Schematic overview of ultra-filtration and reverse osmosis of digestate*. Melse et al., 2004.

The separation of the liquid and solid part can be done via different techniques, centrifuge is one of them. The dry matter content of the solid part is around 33% without heating and it is relatively high in phosphate and can for instance be composted (Melse et al., 2004). In volume percent it is a small part: 9%.

When the liquid part of the manure or digestate is separated from the solid part the liquid is coming under pressure through some membranes during the ultra filtration. The membranes are able to filter out some particles because of their difference in size. After this process phosphate and organic matter stay behind in the concentrate. Also pathogens will be filtered out so a sterile product is the result. The liquid passed by the membranes is called the permeate and goes to its next step for the reverse osmosis. With reverse osmosis the permeate is pressed in reverse direction through a semi-permeable membrane. The salts stay behind in the membrane and the liquid is almost completely clean. Nitrogen and potassium end up in the concentrate (Stevens, 2008). This concentrate can be used as a fertilizer.

Reverse osmosis is a process that can be used in all kinds of other processes. It was for example used in a trial setting to purify municipal waste water in Amsterdam in the beginning eighties. In the standard procedure of aerobic purification high concentrates of N and P left over. With reverse osmosis these can be filtered out as well as the salts (Van den Heuvel, 1981).

2.2.2 Export

The entrepreneur not always chooses to disperse the digestate in the region. Economically it can be attractive to export besides raw manure also digestate. It can be transported outside the region or to foreign countries. Having allowance for this is only possible when the entrepreneur fulfills EU-regulation (1774/2002) (Melse et al., 2004). This regulation means that for exporting manure a heat treatment is obliged. The regulations with regard to hygienisation apply also for digestate. The product should have been for at least 60 minutes at 70 degrees. In principle most bio fermentation installations have available the heat that is necessary for this hygienisation (Melse et al., 2004). The manure export doubled in 2006 in relation to 2005. In 2006 100,000 tons fermentated and hygienised pig manure was exported (Kasper et al., 2007).
An advantage of transporting manure abroad is the removal of phosphate from the Dutch agriculture. In the Dutch agriculture much more phosphate is produced than can be taken up by crops. Normally phosphate can be bonded by soil particles, but

because of shallow drainage phosphate can be easily drained to the surface water where it causes environmental problems. When the quantity of phosphate increases in the soil the capacity to bond extra phosphate to clay-complexes decreases (Schoumans et al., 2004).

Techniques
To heat the raw manure in most cases it is first separated and the solid fraction is hygienised. The manure can be transported via an oil heated jack-screw for around 1 quarter. Afterwards it will be stored in isolated tanks where it can stay for 1 hour at 70 degrees. Another possibility is blowing steam into a jack-screw. The time until the manure is heated takes only 5 minutes (Melse et al., 2004).

Germany and Belgium
Most of the exported manure goes to Germany. However Germany has some stringent regulations to allow Dutch manure. To export hygienised digestate the Dutch food safety authority has to take micro biological samples 4 times a year. The importing federal state should give permission to get the manure imported.
The next scheme shows the time schedule for exporting manure to Germany (Kasper et al., 2007).

Table 2.2 *Year overview of manure exporting to Germany* (Kasper et al., 2007).

Month	**Activity**
July-October	Export to arable farmers (storage)
November-February	No manure export
March-April	Disperse exported manure immediately (no storage)
May-June	Nothing (growing season)

To export manure to Germany also a health certificate is necessary to prove the manure is free from pathogens. For hygienised digestate such certificate is not necessary, but the installation has to be approved. Another extra demand is that hygienised manure to cattle farmers has to be heated at least 20 minutes at 133 degrees (Kasper et al., 2007).

For Belgium the arrangements concern unprocessed manure. For these the same goes as for Germany. To export hygiensised digestate an acknowledgement of the Dutch food safety agency is necessary by taking samples. Like for Germany also for Belgium goes that a health certificate is not necessary for hygienised digestate only an acknowledgement of the installation is sufficient (Kasper et al., 2007).

Despite the fact that it becomes more difficult to get rid of the manure within The Netherlands, exporting manure or digestate is not that easy as it seems in practice. This because of the stringent regulations. To be informed of all regulations and to arrange with and to find suitable farmers abroad is difficult. The most efficient is to export as much manure or digestate to only 1 farmer, but the exporter has to find him (Bosschloo, 2008). Moreover, it is for a farmer or manure trader difficult to get the license to be allowed to export manure. The export prices abroad which the Dutch farmer has to pay are quite high including administrative costs and hygiene measurements (Boschloo, 2008). However, the attractiveness of exporting manure or digestate depends on the cost price of manure processing and the new SDE subsidy regulation as well as the cost price of co-products for fermentation (Kasper et al., 2007).

2.3 Region oriented studies on bio products

As mentioned in the objective a region oriented view plays a role in this research. To look at other regional studies it is interesting to investigate whether there are views which can be useful for this research. That is why this part will be about studies in the past with the focus on regional projects concerning bio products. Some studies are described below and in the end an overview of their main focus point(s) is given in table 2.3. With these studies it will be clear that there are other regional orientated studies with bio products, but it will be also clear that there are not many studies about further processing of digestate.

1. In the Northern part of the province of Limburg in Ysselsteyn an initiative of a research project with co-fermentation was conducted in the period of 1998-1999. This to study the practical feasibility of co-fermentation in The Netherlands for a specific region. The main goal of the project was to get sufficient basis between different stakeholders. This cooperation was between manure producers (cattle farmers), manure consumers (arable farmers), energy producers and a producer of a waste flow. The aim was to get a long term relationship between these stakeholders and to see the importance for this. Because in this region it is not always possible to disperse all the digestate in the direct region other regions have to be found that can store the surplus. In this case it concerns especially the solid part (Kuikman et al., 2000).

An advantage of this is also that the dairy cattle farmers have a net export of phosphate because the solid part contains most phosphate. The liquid part will stay in the close neighborhood.

2. Another regional project has been done at a test farm in Vredepeel. In this project a comparison between pig manure and pig digestate has been made. Besides of that the purpose was to attract the interest of entrepreneurs to work together in a cycle and discover the (im)possibilities of co-fermentation and the further processing of digestate. The willingness to apply digestate among farmers was also a reason to conduct the project (Van Geel et al., 2007). The conclusion of the project was that the digestate is a good fertilizer, but further research is necessary to determine the working of nitrogen in digestate of pig slurry.

3. In the province of Zealand in 2006 a study was conducted with pruned wood and other waste products with a wood-like structure. The purpose was to investigate sustainable ways to process this wood and other products. Possibilities to process products in a sustainable way are applying these in local, regional and inter regional solutions. The bigger the region the bigger the amount of products that can be processed. The conclusions for this project were that co-fermentation is a good way of processing the products, but the environmental consequences decrease when transport distances increase. Also the possibility to burn the products in heat-power engines in the local area is a sustainable way of processing (Salve et al., 2006).

4. In the north east of the province of Drenthe, in the area called De Monden, Alterra conducted a study for different scenarios for this region. The municipality wanted to know whether the agricultural activities can have good perspectives for the future. One issue in this study was the winning of energy from co-fermentation. The conclusion for this was that it has good perspectives for the future provided that the

government can guarantee for subsidies. The production of wind energy and crops for biofuels will give resistance by the public and will not cause much more employment (Agricola et al., 2006).

5. For the province of Flevoland a study by Energy research Centre Netherlands was conducted to find out different routes to make the need for energy more sustainable (Mourik et al., 2006). Like in the study from Agricola et al. (2006) also for co-fermentation the possibilities in this region has been determined. Many farmers in The Netherlands see the bad economic results in their main activity of producing food as a reason to find other ways to increase their income. Co-fermentation can in that case be a solution. It seems to be according to Mourik et al. (2006) that cooperation between more farmers increases the economic rendement.

6. Hanegraaf et al. (2007) conducted a study to investigate the sustainability of 'green' energy. This study was especially directed on the consequences of bio-energy on land use and soil quality in The Netherlands. A conclusion was that co-fermentation has a good influence on soil quality. This conclusion was made on the hand of some indicators like minerals, organic matter and land use. Restrictions for this were however that the system is decentralized, land restrained and the digestate should be utilized optimal to compensate the breaking down of organic matter. From the other side there are also some threats. A tense relation can arise between the function of digestate as soil improvement and the legal restricted amount of this digestate. The risk is that too little organic manure will be come back to the land via digestate and the soil will attenuate (Hanegraaf et al., 2007).

7. A technical research about nitrogen maximum levels was conducted by Erisman et al. (2000). Normally environmental goals have been set for the country in general. This study concluded that regional goals are more important and maximum amounts for nitrogen per region should be calculated. This because of the regional differences in emission and concentration of agriculture. Also nature is not homogeneous in The Netherlands. Via different kinds of models all sources of reactive nitrogen are involved including regional factors to calculate the maximum levels for nitrogen per region. The maximum levels are based on that amount within it will not be harmful for the environment. Especially in manure concentration regions close to nature areas the import of nitrogen should be reduced considerably. The main issue is that reactive nitrogen is on the basis for setting new policy and to prevent averting. Solutions are needed to reduce the amount of reactive nitrogen (Erisman et al., 2000).

8. In the south-east of England trials have been done with soils growing winter wheat and looking at the leaching out of nitrogen. It became clear that the effect of leaching nitrogen of organic nitrogen fertilizer applied in the autumn is bigger than mineral fertilizer applied in spring. The following practices have been formulated to prevent the risk of leaching nitrogen. 1. minimizing the area spring crops, 2. decrease the period when the soil is left bare, 3. avoiding autumn application with N fertilizer or with organic matter, 4. restricting ploughing old grass land (MacDonald, et al., 1989). This study is one of the underlying research topics for the current Manure law.

In table 2.3 an overview from the studies described above shows on which topic it is focused. Most studies focus on sustainable energy. However these are on very different kinds of energy; from energy from wood to co-fermentation and wind energy.

The focus point social-economic concern environmental and human cooperation and the economics of this for producing sustainable energy. To conclude it can be said that there are studies about digestate, but only the unprocessed variant. No interest for different digestate products is in the studies.

Table 2.3 *Schematic overview of the different regional studies and their focus points.*

Study no.	Region	Sustainable energy	Nutrients/soil	Social economic	Digestate
1	Limburg Ysselsteyn	X		X	X
2	Vredepeel	X	X		X
3	Zeeland	X			
4	De Monden	X		X	
5	Flevoland	X		X	
6	Different regions NL		X		X
7	Different regions NL		X	X	
8	South-west England		X		

2.4 Economical aspects of bio fermentation and digestate processing

This part is about the economics of producing sustainable energy with emphasis on bio fermentation installations. What are the important subsidies and cost factors and how are fixed and variable cost divided? What about the costs of investment and the pay back period? These issues will be outlined below.

2.4.1 Subsidies

Timmerman et al. (2005) studied biogas installations and their economical profit. On a pig farm (300 sows and 2,400 pigs) a positive balance for a bio fermentation installation of € 3,760 was calculated including subsidy for investment (EIA). The pay back period was in this case 9.7 years and the total need for electricity was yearly around 143,400 kWh and 43,800 m^3 gas. When this subsidy was left out of the calculation the balance was almost zero and the pay back period rose up to 11 years. For a dairy farm of 130 cows the negative balance of € 10,750 including the subsidy for investment was calculated. The pay back period was in this case 25.3 years. So for a dairy farm in this case a bio fermentation installation is not profitable (Timmerman et al., 2005).

The data given in this case are from 2003 when the MEP subsidy was still going on. For a good understanding of these subsidies they will be explained below.

EIA

EIA (Energy Investment Allowance) is a fiscal regulation and is meant for entrepreneurs who want to invest in energy saving techniques. For being involved in this regulation the entrepreneur should invest at least € 1,200 in energy investments per calendar year. Besides of that an energetic yield of 35% should be made per year. In that case 44% of the total investment can be deduced from the total fiscal profit of the firm. The exact advantage of this regulation depends on the tax percentage calculated over the profit. In most cases in the agricultural sector the profit is too low to have really advantage of the regulation (Oudman, 2006).

From MEP to SDE
Another important subsidy is the (Environmental quality Electricity Production, MEP in Dutch). This subsidy was set in July 2003. The MEP ended at the end of 2006 and from January 2008 it changed to SDE (Subsidy Sustainable Energy). The MEP is a price subsidy of € 0.097 per kWh for pure biogas for installations smaller than 50 MW. The subsidy goes for both electricity delivered to the public network as for private usage. The MEP subsidy has duration of 10 years per installation that requests for subsidy. The new SDE regulation determines that the subsidy depends on the actual market prices of electricity (Oudman, 2006). The SDE subsidy is € 0.12 per kWh including the price for electricity which is not the case for the MEP subsidy and has a duration of 12 years (Ypma, 2008).

2.4.2 Profitability increasing factors

As said before most bio fermentation installations do not only have animal manure for fermentation as it is more efficient and productive to add some co-products. The own usage of electricity produced from the installation is a factor that determines the profitability. Generally speaking it is more attractive to save public energy and use as much as possible energy from the own installation. The amount of saving energy determines the profitability. So the size of the firm has to be above average and the dependence of electricity is a factor that determines the profitability. The higher the need for energy on the own firm and the higher the own manure production the more profitable a fermentation installation (Timmerman et al., 2007). Fermentation installations will be only profitable when they are above the average firm size. The more manure is available the bigger the installation can be and the costs per energy unit will be lower. The generator engine can be bigger and produce more energy which is relatively cheaper. The profitability of an installation depends also on firm specific conditions.

Timmerman et al. state that a minimum of 4,000 m^3 of manure should be available on a pig farm to set up a fermentation installation. The production of the case described in the previous paragraph produced a little more than this amount.

2.4.3 Revenue and costs indicators

When deciding to build a manure fermentation installation an analysis of different costs and revenue factors should be made. Below, table 2.4 shows the most important costs and revenue factors with description. These revenue and costs indicators apply for most standard fermentation installations.

Table 2.4 *Revenue and costs factors for a bio fermentation installation*. (Van Seventer, 2006).

Revenue factor	Description	Details
Subsidy	Subsidy per produced kWh and an allowance amount for tax	
Electricity/heat sales	Price per kWh to the public network	
Saving of artificial fertilizer	Saving of the amount of fertilizer *only when the installation is part of a farm*	Due to the higher fertilizing effect of digestate
Fixed costs		
Investment of installation	The initial investment of a fermentation installation	Dependent on specificities of installation and mostly including enlargement of terrain and silo's for co-products
Insurance costs	Insurance of the installation	
Accountant costs	Yearly amount for the accountant	To fulfill the regulation of the MEP subsidy
Measurement and transformer costs	Hiring of transformer and measuring the installation process	
Variable costs		
Maintenance generator engine	Based on a maintenance contract	
Maintenance whole installation	Based on a maintenance contract	
Transport ointment oil	Refresh and transport oil	
Manure sales costs	Transport and process costs	Extra costs for manure transport to other stakeholders including sample taking
Supply maize	Financing arable ground, sowing and yielding costs, processing cost	Costs depends on purchasing or self breeding maize
Supply other co-products	Purchasing and transport costs	

Pay back period

The pay back period is the term in which an initial investment can be earned back. To calculate this term the initial investment is divided by the yearly revenues. This ratio in years indicates after how many years the installation will make profit for the firm. The pay back period is dependent from a number factors. The working hours of the engine should be that high as possible as the fermentation process is a continuous process the engine will work as much hours as possible. In practice the percentage of working hours will be around 90-94%. Also enlargement of the engine capacity can reduce the pay back period and adding high-quality co-products to the process. (Van Van Seventer, 2006). See also figure 2.2 for difference in gas production of co-products. General speaking a fermentation installation is not profitable when only manure is fermentated. So co-products are inevitable.

Indication of exploitation costs of different techniques

Melse et al. (2004) made for different techniques a general determination of costs. In table 2.5 an overview is shown.

Table 2.5 *Exploitation costs for some manure processing techniques* (Melse et al., 2004).

Technique	Exploitation costs
Manure separation	€ 2-5 per inserted m^3
Jack-screw hygienisation	€ 5-7 per ton
Ultrafiltration and reverse osmosis	€ 9 per ton

Perspectives for co-fermentation
Since 2007 the grow of the biogas sector has decreased drastically. There is a lot of discussion about the subsidy per kWh. At the moment this is € 0.12 per kWh together with the price of electricity, but not many entrepreneurs think this is high enough. Besides of that the prices for co-products also increase dramatically. The Dutch council of rural area stimulates the usage of bio energy and pleads for an energy network that government and provinces stimulates to support bio energy (Ypma, 2008). From the other side the high resource prices seem to be a problem. Traders in different kinds of food waste flows are making huge profits these days. The export to Germany of these waste flows has almost stopped; the demand in The Netherlands exceeded the supply. For comparison a German biogas producer receives around twice as much subsidies as a Dutch biogas producer. Besides the subsidies are granted for 20 years in Germany. Smaller installations up to 500 kW receive an extra subsidy of 4 cent to stimulate installations on farm scale because it is not profitable to transport manure; manure has to be treated at the place where it is available (Ypma, 2008).

For the coming years many steps can be made in the fermentation process. Improving of the digestability of the inputs is important to degrade the biomass in a more complete way. Also a better understanding in the dynamics of the bioflora can help to optimize the fermentation process. Good monitoring of the process will provide important information for this (Weiland, 2006).

2.5 Relevant policy

Digestate does not have its own policy. The European manure policy goes for digestate as well. For that reason the relevant *manure* policy will be discussed in this paragraph. Since livestock farming in The Netherlands goes along with an overproduction of manure in some regions with environmental problems the government was obliged to set regulations for these problems as a consequence. From the mid '90's the pressure of all regulations become higher and higher for farmers. This part will describe the main flows of the manure policy with its implications for digestate.

2.5.1 Nitrate statute

The Dutch manure policy is based on the European nitrate statute 91/676/EEG. In this extensive statute the next 4 subjects are elaborated (Anonymous, 2008c):

- Usage norms for the nutrients nitrogen, phosphate and potassium (N,P,K) in animal manure and artificial fertilizer that may be dispersed on different soils and crops.
- Usage norms for the way of adaption of manure and the period of dispersion.
- Usage norms for the number of rights to have animals to restrict the amount.
- Regulations for the transport of manure to prevent 'dumping' of manure.

The most actual version of the manure policy is from January 1 2006. Every 4 year the minister of agriculture evaluates the current policy and considers adjustments to the Dutch situation (Anonymous, 2008c).

For farmers in The Netherlands usage norms for nitrogen and phosphate are determined by the European government. For nitrogen from animal manure an amount of 170 kg per hectare may be dispersed.

The usage norms for phosphate are not different for the type of soil. However there is a difference in the usage of the soil. The norms for soils used for agricultural crops are lower than soils used for pasture land. Besides of that the norms are decreased every year with around 5 kg per ha. The aim with phosphate fertilizing is to come to a balance between input and uptake by the plant. A loss of 5 kg is inevitable but despite of that the norms are sharpened every year. For 2008 the norms for grass and arable land are 100 and 85 kg respectively (Van Grinsven, 2006). These norms are made for animal manure. In digestate the quantity of nutrients is the same as the input of manure including co-products. The policy makers determine that digestate is also animal manure and therefore for digestate the same regulations apply.

2.5.2 Total nitrogen usage norms

The nitrogen usage norm is the amount of nitrogen that is allowed to use per calendar year per hectare. The nitrogen usage norms depend on crop and kind of soil. These norms are based on the average fertilizing advices but to achieve environmental goals some deduction have been applied. So in these norms the minerals for both animal and artificial fertilizer have been calculated. To calculate these norms precisely the working coefficient of nitrogen from animal manure is compared with the 100% working coefficient of artificial nitrogen. The working coefficient for nitrogen from slurry is generally speaking 60% and 65% for arable land on sandy and loess soils. For pasture land the working coefficient is also 60% when the grasslands are grazed the coefficient is 45% (Anonymous, 2008d).

Table 2.6 *Nitrogen usage norms for grass land kg N per ha. 2008* (Anonymous, 2008d).

Grass land and usage	**Clay**	**Peat**	**Sand/Loess**
Grass land with pasturing	345	265	275
Grass land with mowing	365	300	345

Table 2.7 *Usage norms for some crops in 2008 in N per ha.* (Anonymous, 2008d).

Crop	**Clay**	**Sand/Peat/ Loess**
Starch potato	255	230
Sugar beet	160	145
Winter wheat	230	160
Summer wheat	150	140
Winter barley	150	140
Summer barley	85	80
Maize without derogation	195	175
Maize with derogation	160	155

Table 2.8 *Usage norms for phosphate in P_2O_5 per ha*. (Anonymous, 2008d).

Year	Grass land	Arable land
2008 (definite)	100	85
2009 (indicative)	95	80
2010 (indicative)	95	75
2012 (indicative)	95	70
2015 (indicative)	90	60

2.5.3 Phosphate usage norms

The regulations for phosphate are generally speaking the same as for nitrogen. All kinds of fertilizers are taken into account (animal and artificial). For 2008 the norms are fixed after that year the norms are indicative. No difference in type of soils is made for phosphate. Except for phosphate fixing or phosphate poor soils extra dispersion of phosphate is allowed in this case it is 160 kg phosphate and this extra gift has to be from an artificial fertilizer (Anonymous, 2008d).

For the government manure and digestate are the same: they are animal fertilizers. Before January 1 2006 for digestate other regulations applied when the digestate consisted of more than 50% co-products. Afterwards for digestate always the same regulations applied provided the co-products are on the allowed list. An animal fertilizer is a fertilizer with a part (no matter how big) animal manure. For digestate the only difference is that the working coefficient a little higher (Brenneisen, 2005).

2.5.4 Manure application

Regulations on application of manure have changed considerably during the last few years. These regulations concern in which period the manure may be dispersed and under which conditions. The following conditions are important which are the same for digestate (Anonymous, 2008d):

- It is forbidden to disperse manure on sandy arable and grass soils in the period September 1 – February 1.
- On clay and peat grass soils it is forbidden to disperse liquid manure between 16 September 16 and February 1, fixed manure is allowed.
- On peat and from 2009 on clay arable soils it is forbidden to disperse manure from September 16 till February 1.
- On clay arable land it is forbidden to disperse manure from November 1 2007 till February 1 2008 and October 16 2008 till February 1 2009.
- It is forbidden to apply artificial nitrogen fertilizer from September 16 till February 1 on arable and grass land.
- Animal manure has to be dispersed in an emission free way.

2.5.5 Derogation

Some farms are allowed to disperse 250 kg nitrogen per hectare from animal manure if they have more than 70 percent of their land in pasture for 1 year. These farms comply with derogation.

Grass land only suits for derogation when it is used as a feeder crop. Another important factor of aspect is that derogation only holds for manure from grazing animals. Manure from cage animals is not allowed to use in derogation (Anonymous, 2008c).

Because the nitrate statute is a policy guide for the whole European union the circumstances in different countries can be different. The Netherlands with its high productive fertile soil made a lot of complaints to the European commission to liberalize the usage norms for the Dutch situation a little more. Finally that is why the European commission allowed the derogation. However for the derogation some conditions have been made for 2009. A demand is that the amount of nitrogen in the upper surface water is less than 50 mg/l. However in the Nitrate statue, the depth, time span and spatial level of measuring are not clearly described. These can have consequences for the assessment for reaching or not this amount (Van Grinsven, 2007).

2.5.6 Animal rights system

In 1987 a system of manure production rights was implemented for cattle, poultry and pig farms. Every farm got a reference of production of manure with reference year 1986. This reference applied for the amount of phosphate. In 1998 these manure 'quota' were replaced by pigs rights. This system was a consequence of the outbreak of pig epidemic and the goal of this system was to reduce the number of pigs in The Netherlands. The amount of pig's rights is fixed. The export of manure from poultry stagnated in 1999 due to the grow of the number of chickens. Since 2006 animal rights are the only rights to keep cage animals and have been implemented for all types of livestock except for cattle farms. Farmers can trade these rights (Van Grinsven, 2007).

2.5.7 Economical consequences of manure policy

The sharpening of the manure policy is expected to have economical consequences for farmers. For dairy farmers the sharpening of usage norms for nitrogen on sandy soils leads to a decreasing economical result of € 5-45 per hectare (Van Dijk et al., 2007). The main cause of this is an increase of the fodder costs because their own crop production decreases with less nutrients. The increased fodder costs are not compensated by less costs for artificial fertilizer. On clay and peat farms this is not the case. Arable farmers see a decrease in economical result of € 5-35. The cause of this is the decreasing amount of animal manure that may be dispersed (10-20% less in 2009 compared to 2006). This difference in economical result is made by the fee that farmers get for animal manure. This amount will be less, but the costs for artificial fertilizer will increase.

With regard to the regulations for the amounts for phosphate not many problems are to be expected. In most areas there are little surpluses but, generally, with fertilizing manure rich in organic matter and low in phosphate a balance can be created. In areas with bigger scaled farms, however, other ways of fertilizing should be applied for instance with fertilizing crops (Van Dijk et al. 2007).

2.5.8 Policy for artificial fertilizer substitutes

In 2006 the minister of agriculture had the opportunity to discuss artificial fertilizer substitutes in Brussels in a workshop. At this moment the minister met some resistance by the European Union. The resistance was based on the fact that The Netherlands, according to the other states, had enough advantages such as the derogation permit. In 2007 the subject about artificial fertilizer substitutes could be set on the European agenda again if The Netherlands would take the initiative. The actual status around this subject is as follows (Van Dijk, 2007):

- A request to point products as artificial fertilizer substitutes can only be brought on the agenda with the next request for derogation. In this case implementation in The Netherlands will not be before 2010.
- Only small rest flows from manure processing make a chance to be seen as artificial fertilizer substitute. So this is not the case for digestate but after more research this can be the case for the concentrate after reverse osmosis.
- Thorough research has to be done on the environmental effects and working of artificial fertilizer substitutes.

When products would be considered for artificial fertilizer substitutes they should meet the following requirements (Van Dijk, 2007):

- The nitrogen working ratio should be 100%; the same as for artificial fertilizer.
- The working ratio of other minerals should be the same as for artificial fertilizer.
- The contents of nutrients is know.
- The product is free from pathogens.
- They are to be distinguished visibly and by odor from animal raw manure.
- The maximum of 18 g per kg liquid fraction exists of organic matter.

At this moment (2008) the acknowledgment of nitrogen concentrate, i.e. RO concentrate, from processed manure is still not there by the European commission. This means that more than 170 kg N per hectare may be applied. Getting this concentrate accepted as artificial fertilizer substitute is a long term project and from 2009 small scaled field trials will start. The minister of agriculture intends to get this acknowledgment by diplomatic ways because too powerful actions can bring the derogation for Dutch farmers in danger (Anonymous, 2008e)

2.6 Acceptance of manure and digestate

Termeer et al. (2007) interviewed in their study both manure producers and manure users. Users of manure, especially arable farmers, state that they are more concerned with the environment than in the past. Not only because of the regulations but also because of the social involvement and pressure from outside the agriculture. But the way of thinking about manure has most changed because it has financial consequences for the farmer. Farmers who receive manure have different opinions about the manure regulations. Some think that the regulations are necessary and these will prevent the drainage of nutrients to the surface water. Besides, they say they can deal with the stringent regulations via a good way of management. Other farmers think the norms are much too stringent and these will harm their financial results because of a diminishing crop production.

Almost all receiving farmers of animal raw manure are willing to accept more animal manure because of the high prices farmers receive. On the long term some farmers state that the manure regulations will determine their choice of crops Termeer et al., 2007).

Since manure and digestate are the same in the Manure law farmers do not have to choose between them because of money. The tariffs for the receiving farmers are for both the same. When the rate of acceptance of manure increases the manure surplus should be less. Because of the more stringent getting regulations processing techniques for digestate will be more attractive and more profitable. It can be profitable because the costs for processing manure and digestate can be lower than just removing it unprocessed. Giving value to manure can be in this context more interesting (Brenneisen, 2005). Techniques to reduce the contents of nutrients and to make a homogenous composition of the processed manure can be solutions to reduce the manure surplus. These techniques will produce fertilizing products that are homogenous and with an artificial fertilizer reaching working coefficient. Precise fertilizing is an important factor for farmers (Brenneisen, 2005). Some crop farmers think digestate is less attractive for them because of the lower amount of organic matter it contains compared to raw manure. Because there are no acceptance factors known for digestate, in the results is worked with assumed levels. On the basis of the fact that the nutrients in digestate are easily to be taken by plants and less nutrients go lost the factors are assumed to be some higher. A disadvantage is the way of dispersion of raw manure or digestate on the land. The machines which are used for this are quite heavy and cause damage to the soil (Tijink, 2004). Dispersion of artificial fertilizer does not have this disadvantage.

3 Materials and methods

3.1 Case description

The case elaborated in this report is a bio fermentation installation in Salland, called *Biogreen*. The interesting fact of this installation is that it produces not only electricity and heat like many other similar installations but another activity is processing of the digestate and making a valuable product of it.

3.1.1 Technical description

The produced digestate is the starting product for some next steps to get a kind of artificial fertilizer at the end. In this case 'artificial fertilizer' means that the produced concentrate should have the same features as conventional artificial fertilizer. The next steps show how the installation of this study is working and which products are used (Oppewal, 2008):

Phase 1 *Biogas production*

1. The input materials, 67,500 tons per year, pig manure (73%), poultry manure (9%), maize silage (11%), tulip bulbs (2%) and food waste (5%) are mixed and grinded and pumped into 2 pre-fermentators of 600 m^3 each. The fermentation will start and the mixture stays a week in these silos.
2. This pre-fermentated product flows to the main fermentator of 1800 m^3 and it stays there for 40 days[2] at 40 degrees. 2 gas burn engines burn the produced gas. The total electricity produced is 1.8 mW per year.

Phase 2 *Digestate processing*

1. The digestate is separated in a solid and liquid part via pressing by a decanter. The solid part, 30% dry matter, is rich in phosphate, 18 kg P_2O_5 per ton. It can be possible to enlarge the dry matter content to 80% with the produced heat of 1 heat power engine in phase 1. This solid part will be sold as compost or granulate outside agriculture. In this step and in step 4 water is a rest product. Per year this is about 40,000 tons which can be expelled to the sewage for a fee.
2. The liquid part goes with high speed through a filter, ultra-filtration. The thick part goes back to the fermentator.
3. The thinner part flows through electrically charged membranes where it is cleaned from salts, the reverse osmosis process.
4. The result of the reverse osmosis is 2 liquids. One liquid resembles water and can be expelled to the sewage. The other liquid is dark colored and is very low in phosphate and organic matter. This is called the RO concentrate[3].

In figure 3.1 the processing scheme of Biogreen is shown. In table 3.1 the product flows are separated in an input and output flow with their corresponding products. The bold lined items in the figure correspond with the items in the table. In table 3.1

[2] Normally the pre-fermentated product stays in the digester for 72 days. For Biogreen this is shorter (42 days) because of their aim to process minimal 55,350 tons of raw manure.
[3] RO concentrate is not yet accepted as a substitute for artificial fertilizer.

‘liquid digestate’ means the liquid part after the decanter that is not going to be dried. For Biogreen the fictive liquid digestate will be the result when ultra filtration and reverse osmosis will not take place. In paragraph 3.3 this term will be part of 1 scenario. The input and output quantities are closing for the process. This means that input and output are the same.

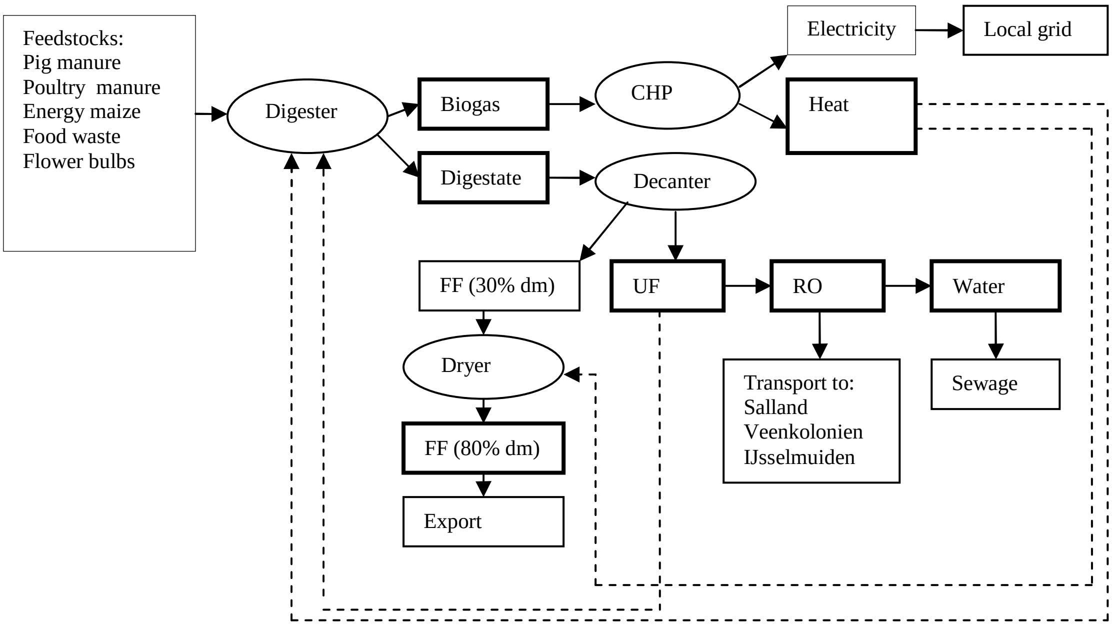

Figure 3.1 *Process scheme of complete installation of Biogreen*.

Table 3.1 *Input and output for the different products per year and their composition* (Oppewal and Veldhuis, 2008).

	Products	Quantity (tons)		Composition (N,P,K)		
Input	Manure	55,350		8.2[1]	5.0[1]	7.4[1]
	Co-products	12,150			Unknown	
Energy products output	Biogas	6,750			-	
	Heat	-			-	
Digestate output	UF concentrate	14,000		8.0	6.0	7.0
	RO concentrate	10,000		6.8	0.6	11.5
	Water	28,750	+		-	
	Liquid digestate	52,750		6.7	1.0	7.2
	80% dm product	8,000	+	9.3	19.2	5.9
	Unprocessed digestate	60,750		7.0	3.4	7.0

[1] Composition values assumed from Koch Bodemtechniek (2008).

3.1.2 Organizational structure

Biogreen is an installation which started in August 2007. The installation is the product of a cooperation project of 50 pig farmers in Salland. Because of this cooperation a cooperative organizational structure has been chosen for. Each of these 50 farmers are members and produce together more than 55,000 tons manure. In 2001 the idea rose to become less depended on the manure market. On the basis of this idea was the fact that the distributors took a too big financial share of the price farmers have to pay to get rid of their manure, according to the initiators of Biogreen,. At that moment a suppliers organization was founded. After a short time the idea was to found a cooperative with the goal: processing manure with the participating farms. In order to realize this a lot of experience in Germany have been done. In Germany the technical and organizational status is at a more advanced stadium than in The Netherlands. In 2001 the decision was made to build a manure fermentation installation. It took a lot of time, 4 years, to get all permits to start building. Because of this long duration Biogreen almost missed the MEP subsidy.

The installation was built on terrain of a contract worker who also does the practical work and who does the logistics for the manure transport. The member-farmers who all live in an area of 10 km around Biogreen produce 200 up to 6,000 m^3 manure each. More farmers want to participate but for capacity reasons they are at a waiting list (Ten Hove, 2007).

3.1.3 Financial aspects of Biogreen

In the next table an overview is given on the way of Biogreen is financed. The total cost for the whole installation were € 6.6 million.

Table 3.2 *Finance structure Biogreen.* (Ten Hove, 2007).

Way of financing	**Amount (€)**
Financed money (70%)	4,620,000
Subsidies (15%)	990,000
Supplied manure (€ 15 per m^3)	990,000
Total	6,600,000

The total installation costs of € 6.6 million are financed for 70% and 10-15% was received from subsidies. The rest of the needed money was brought together by the farmer-members. Once only they paid € 15 per m^3 manure that they plan to deliver the next years.

Besides this start-up capital farmers annually pay per m^3 manure a price conform to the market price of manure. When Biogreen performs better than expected the farmers get back a part of this (Ten Hove, 2007).

3.2 Description of regions

The aim of Biogreen is to get rid of the nutrients in the digestate. The RO concentrate, rich in nitrogen and potassium, should act as an artificial fertilizer substitute in the region of Salland. In this part this region together with the municipality of Kampen and the region Veenkoloniën will be described to get familiar with them. This part will also describe factors which determine how many nutrients can be placed in that region. First the 3 regions will be described and afterwards a table shows the complete overview with relevant data about these regions.

3.2.1 Salland

The Central Bureau of Statistics defines The Netherlands in 66 agricultural regions. One of these regions is Salland. The region of Salland consists of the municipalities Deventer, Olst-Wijhe, Raalte, Rijssen-Holten. The data of these municipalities are updated from the most recent political rearrangements. Table 3.3 shows the fertilizable surface of the municipalities per hectare. The fertilizable surface means all the culture land where fertilizing with animal manure is allowed. Not included is land out of production (mostly grass) and land growing wood (CBS, 2008).

Table 3.3 *Total fertilizable culture area of municipalities of the region of Salland in 2006*. CBS, 2008.

Municipality	**Surface land (ha.)**
Deventer	7,873
Olst-Wijhe	7,695
Raalte	14,625
Rijssen-Holten	4,965
Total (Salland)	**35,158**

Salland is a typical pasture area with a high amount, 68%, of grass of total fertilizable culture land in 2006. The arable part in Salland is 32% from total fertilizable culture land (CBS, 2008).

Soil type

The general soil type in the region of Salland is sand. The region is limited in the west and south by rivers which are responsible for a small stroke of heavy clay (De Grote Bosatlas 52e edition, 2006).

Animals, manure and minerals

Salland is a typical region for pig farmers. This can be concluded from the fact that pigs have a relative big share in the total amount of cattle in Salland compared to the rest of The Netherlands.

Most manure that is produced in Salland is liquid manure that is suitable for fermentation at Biogreen. The total produced amount of liquid manure in Salland is 1.8 million tons and 337,000 tons liquid pig manure (CBS, 2008). However Biogreen can only accept around 55,000 tons per year.

3.2.2 Municipality of Kampen

The third region is the region of the place IJsselmuiden in the municipality of Kampen. This municipality is situated in the south-west of the province of Overijssel. The municipality has a fertilizable culture area of 10,481 ha. in 2006 (CBS, 2008). Like Salland also Kampen is a typical cattle region with a lot of grass land (91%) and 9% arable land.

Soil type

The municipality of Kampen is situated close to the IJsselmeer and the river IJssel flows through it. This causes the soil to generally consists of clay (Grote Bosatlas, 2006).

3.2.3 Groninger Veenkoloniën and Westerwolde

The second region which will be described is a region that is considered to be an agricultural area with possibilities to expand the nutrient capacity of Salland. The Groninger Veenkoloniën and Westerwolde (in short Veenkoloniën) is according to the CBS an ‘agricultural area’ just like Salland. The Veenkoloniën are situated in the south and south-east of the province of Groningen and it thanks its cultural-agrarian landscape to a rich history of winning peat. The Veenkoloniën consists of the municipalities Hoogezand-Sappemeer, Pekela, Stadskanaal, Veendam and Vlagtwedde. Table 3.4 gives a division of the fertilizable culture area per municipality.

Table 3.4 *Total fertilizable culture area of municipalities of the region the Veenkoloniën in 2006*. CBS, 2008.

Municipality	**Surface (ha.)**
Hoogezand-Sappemeer	3,418
Pekela	3,127
Stadskanaal	8,073
Veendam	4,312
Vlagtwedde	11,648
Total Veenkoloniën	**30,578**

The Veenkoloniën in contrast with Salland is a typical arable area with a share of 83% in arable land from total culture land in 2006 and 17% grass land (CBS, 2008).

Soil type
As described above the Veenkoloniën thanks its history to the winning of peat. This resulted in a high percentage of peat in the Veenkoloniën approximately 60% is peat. The municipality of Vlagtwedde mainly consists of sand so the rest of the region has a sandy soil (Grote Bosatlas, 52e edition, 2006).

3.2.4 Germany

Another region with possible nutrient capacity for Biogreen are some parts in western Germany. The exact place in Germany is very ambiguous. Biogreen does not have to pay for transport, but receives no fee for it. In Germany there is no surplus of nutrients so German farmers are willing to receive this digestate and pay the transport and related costs. For efficiency reasons it will be most attractive to transport the solid part of the digestate which consists of 80% dry matter. This is very dry matter that is suitable for export[4]. In the description of the scenarios in paragraph 3.3 this solid part will come back.

3.2.5 Nutrient capacity of the regions

Above a short description and some general information about the regions was given. In table 3.5 a complete overview of the nutrient capacity per region is presented. *Production* means the amount of nutrients produced in a region. *Land capacity* means the amount of N and P that can be dispersed on land within the legal usage norms for animal manure. The difference between these values gives a shortage or surplus of nutrients. The *degree of utility* means the production as a percentage of the land capacity. In all the regions transport of nutrients takes place and nutrients from other regions are transported to fill up the shortage or to reduce the surplus (Salland). This transport is called in the table *supply* and *removal*. When the difference in supply and removal is added to the production *usage* is the result. It can be seen that after transport the shortage for all 3 regions is still not filled up completely. This becomes clear in the *remaining capacity* for nutrients. For example for Veenkoloniën the result is that in 2006 around 80% of the fertilizable nutrient capacity of land is fulfilled (CBS, 2008). This is made clear by the *degree of utility after transport*. This is the usage as a percentage of the land capacity. When the land capacity is completely utilized this percentage is 100%. For Salland for example there is space for 2% extra nitrogen from animal manure. In all regions nitrogen is the limiting nutrient. For

[4] For export hygienisation is required. The 80% dry matter product fulfills for export because of the heat treatment for drying.

Veenkoloniën and Kampen more capacity is left. This space can potentially be used for manure/digestate from Biogreen. It is also possible to fertilize with extra nitrogen from artificial fertilizer. The usage norm for nitrogen from artificial fertilizer is in most situations wider. The usage norms for phosphate for animal manure and artificial fertilizer are the same.

Table 3.5 *Nutrient balance of the regions in 2006*. Derived from CBS, 2008.

	tons	**Salland**		**Kampen**		**Veenkoloniën**	
	Nutrient balance (tons)	**N**	**P**	**N**	**P**	**N**	**P**
A	Production	9,617	3,933	2,260	833	2,372	961
B	Land capacity	8,123	3,588	2,582	1,129	5,548	2,728
	Surplus/Shortage (A-B)	1,494	345	- 322	- 296	- 3,176	- 1,767
	Degree of utility	118%	110%	88%	74%	43%	35%
C	Supply	656	310	123	67	2,739	1,545
D	Removal	2,340	1,314	174	98	534	305
E	Usage (*A*+*C*-*D*)	7,933	2,929	2,209	802	4,577	2,201
	Remaining capacity (*B*-*E*)	190	659	373	327	971	527
	Degree of utility after transport	97.66%	81.63%	85.55%	71.04%	82.50%	80.68%

3.3 Scenarios

From table 3.5 it becomes clear that in Salland is a surplus of nutrients. Table 3.5 is also the beginning situation for the regions when there is no interaction of Biogreen. To get rid of this surplus a possibility can be to transport it to other regions. At Biogreen nutrients can be removed in different ways: separating the digestate it into a part of expellable water and by transporting it. In table 3.6 some scenarios will be described for Biogreen which give different ways to deal with its products and which will give more insight in the economic options. The names for the products which are used are the same as in table 3.1. The '0' scenario is the situation all the manure which Biogreen receives stays unprocessed. All the other scenarios deal with a form of processed or unprocessed digestate. Scenario 4 deals with the fact that the RO concentrate is completely accepted as 'artificial fertilizer' so the legal norms for RO concentrate are the same as for real artificial fertilizer. The amounts of digestate, 80% d.m. digestate and RO concentrate are based on the numbers given in table 3.1. Some of the scenarios are theoretical for Biogreen, like scenario 2. However at some firms only this activity can be attractive to get rid of a surplus of phosphate. When 8,000 tons will be dried to 80% dry matter the rest will not stay unprocessed digestate as stated in this scenario, because of the presence of the ultra filtration and reverse osmosis installations at Biogreen. However, for an overview it can be worthy to look at this alternative. Another possibility could be that all the digestate will be dried to 80%, but this is not an option because nitrogen dissolves in the rest water and is in this case a second fertilizer.

Table 3.6 *Scenarios for removal manure or digestate and other products from Biogreen*.

	Scenario	Description
0	Unprocessed manure	Direct removal of 55,350 tons unprocessed manure in Salland/other regions; no intervention of Biogreen.
1	Unprocessed digestate	Direct removal of 60,750 tons unprocessed digestate in Salland/other regions.
2	80% d.m. digestate and liquid digestate	Removal 8,000 tons digestate with 80% d.m. to Germany, rest, 52,750 tons, liquid digestate in Salland/other regions.
3	80% d.m. digestate and RO concentrate as animal manure (AM)	Removal 8,000 tons digestate with 80% d.m. to Germany, 10,000 tons RO concentrate in Salland/other regions and water to the sewage.
4	80% d.m. digestate and RO concentrate as artificial fertilizer (AF)	Same as scenario 3 but RO is accepted as artificial fertilizer.

3.4 Level of acceptance

The level of acceptance means the willingness of farmers to disperse animal manure on their land in the case they have any nutrient capacity left (Van der Hoek, 2002). According to the Agricultural Economic Institute the level of acceptance depends on region and soil usage (Van Staalduinen et al., 2001). This institute divides The Netherlands in 3 regions: a manure concentration region, a transition region and a shortage region. For soil use a difference is made in soils used for grass, maize and crops. Salland is a concentration area with grass, Veenkoloniën a shortage area with arable farming and Kampen is a transition region with grass (Grote Bosatlas, 2006). On the basis of this some acceptance levels for raw manure and digestate can be determined (see table 3.7). The numbers are from 2003 but it can be assumed that these numbers do not differ that much over years, because farmers use to deal with the same fertilizing plan every year. For the RO concentrate it can be assumed that the level of acceptance is much higher because its working is assumed to be more or less the same as artificial fertilizer: a high working coefficient and it can be dispersed without heavy machinery.

Table 3.7 *Level of acceptance per region for different types of fertilizer* (Van Staalduinen, 2001).

Type of fertilizer	Salland	Kampen	Veenkoloniën
Unprocessed manure	0.95[1]	0.50[1]	0.60[1]
Unprocessed digestate/liquid digestate	0.95[2]	0.50[2]	0.60[2]
RO concentrate as animal manure	0.95[2]	0.90[2]	0.90[2]
RO concentrate as artificial fertilizer	0.95[2]	0.90[2]	0.90[2]

[1] Derived from Van Staalduinen (2001).
[2] Assumed values.

In Germany the acceptance levels for manure or processed manure products are assumed to be 100% because personal arrangements are made between Biogreen and its receivers in Germany. In The Netherlands it is based on the nutrient balance of the region (Van Staalduinen et al., 2001): the capacity does not have to be filled completely with animal manure. Farmers can prefer to use other manure or artificial fertilizer. That is why farmers will not accept animal manure for 100% on their farms.
In order to calculate the remaining capacity corrected for the level of acceptance the remaining capacity in table 3.5 is multiplied by the level of acceptance in table 3.7. The level of acceptance can differ per scenario and depend on the kind of fertilizer. In

table 3.8 the remaining capacities per region corrected for the levels from table 3.7 are shown. The first line in the table shows the remaining capacities from table 3.5. The last line of the table shows values for nitrogen which are calculated on the basis of the fictive division of grass with mowing and winter wheat of 60/40 percent per region. This is because the usage norms for artificial nitrogen differs per crop and soil type and are for some crops much higher than for animal fertilizer. For some other crops the norms are lower. However it can give an indicative number of the capacity of the regions. The numbers are corrected for the soil type as well. Usage norms for nitrogen are shown in table 2.5 and 2.6. To see is that the capacities for artificial nitrogen are much higher than for animal nitrogen because of the fact the norm for grass land for artificial fertilizer is much wider.

Table 3.8 *Corrected remaining capacities per region for animal manure or processed manure products for Dutch regions.*

	Salland		**Kampen**		**Veenkoloniën**	
Tons	**N**	**P**	**N**	**P**	**N**	**P**
Remaining capacity	190	659	373	327	971	527
Corrected remaining capacities						
Unprocessed manure	181	626	187	164	583	316
Unprocessed digestate	181	626	187	164	583	316
RO concentrate as animal manure	171	593	317	294	874	474
RO concentrate as artificial fertilizer	1,595	593	1,051	294	3,214	474

3.5 Calculation methods

3.5.1 Allocation model nutrients

In this part the way of calculating the distribution is explained via a flow diagram. In this diagram some steps have to be followed to come to the end result. These steps are shown below and afterwards a description is given.

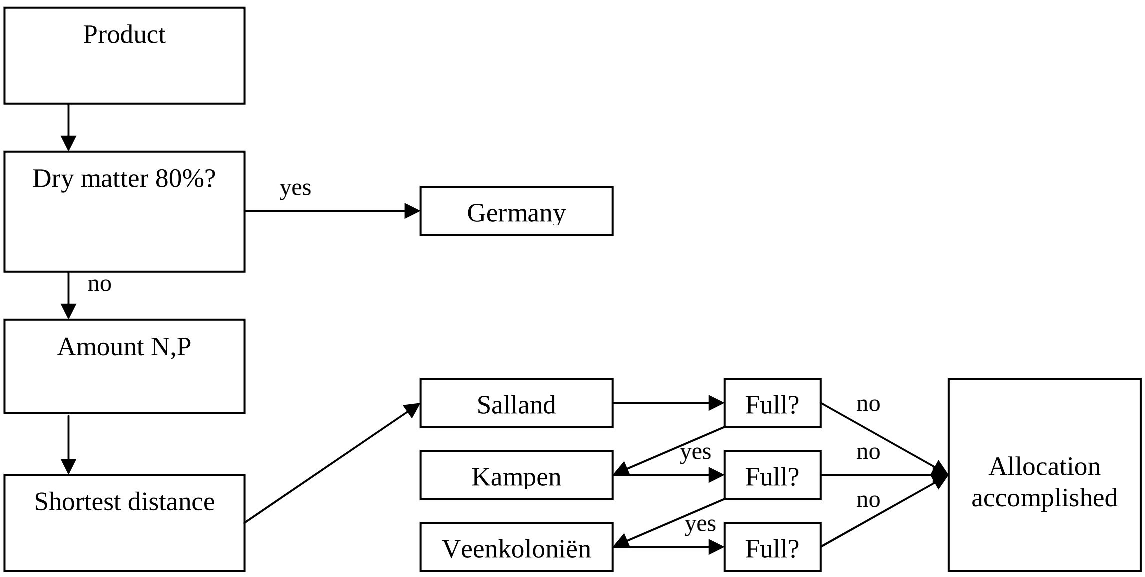

Figure 3.2 *Diagram to determine allocation of manure (products) over regions.*

The model above shows how the amount of manure or other products from Biogreen will be distributed over the regions. The different steps will be described more in detail below.

Product
This means the kind of product which has to be distributed. In the 'only manure' scenario the product is of course only manure. The products can also be digestate, RO concentrate or dry matter material.

Dry matter 80%
When the product concerns dry matter material with 80% dry matter this product will not be distributed over the Dutch regions, but it will immediately go to Germany.

Amount N,P
When the product concerns not the dry matter material. The amount of nutrients have to be determined. When the amount of nutrients is known it is possible to determine how much product has to be transported to a certain region.

Shortest distance
On the basis of the shortest distance a part the product will be transported first to Salland. In other words some part of the nutrients will stay in Salland the rest has to be distributed to other regions.

Full
A certain region is considered to be full when the nitrogen remaining capacity or phosphate remaining capacity (corrected remaining capacities from table 3.8) for a region is reached. When both capacities for N and P are not completely full further distribution is not necessary anymore. When either the nitrogen or phosphate capacity is reached distribution will go to the region which is most nearby. There will be no need to have more capacity left than these 3 regions with Veenkoloniën as final destination. With the products from Biogreen this will not be necessary.

3.5.2 Economical analysis basis situation

Besides a more technical part with the focus on nutrients balances and co-products also the economical part will be taken into account. The economical analysis consist of making a cost-revenue analysis. A scenario is related with both costs and possible revenues. The costs will be split up in different parts:

- fixed cost;
- variable cost.

Revenues

MEP subsidy
The MEP subsidy was at the last moment allotted to Biogreen. New installations do now get the new SDE subsidy. The MEP subsidy fee is € 0.097 per produced kWh. The fermentation process of Biogreen produces 1.8 mW (15,552,000 kWh)[4] electricity which brings a subsidy amount of € 1,508,544.

[4] 1.8 * 1000 = 1,800 kW. 1,800 * 24 hours * 360 days = 15,552,000 kWh per year.

Electricity sales
The price Biogreen receives is € 0.084 per kWh.

Supply manure
The manure from the farmers needed for the fermentation brings in an amount of € 14 per ton. The total amount of manure is 55,350 tons. 49,275 tons is pig manure, 6,075 tons consists of poultry manure.

Sales RO concentrate
The RO concentrate is expected to give a small return of € 5 per ton when it is accepted as substitute for artificial fertilizer. The total amount of RO concentrate is 10,000 tons.

Fixed cost

Depreciation
The cost for investment can be divided into 3 parts. The biggest part consists of the fermentation installation. The cost for Biogreen for this installation were € 4.5 millions. The other installations, the drying installation and the installation for ultra filtration and reverse osmosis, were respectively € 0.6 and € 1.5 millions. The installation has an economical life span of 10 years according to builders of installations (personal communication). Depreciation according to the straight line method prescribes the investment amount dividing by the number of years. The result gives the yearly depreciation.

Labor
The complete installation including the processing of the digestate requires 2 full time equivalents (fte). Besides of that also a manager is needed to lead the cooperation. At Biogreen this manager is not taken into account, because the manager is not an extern person, but a member of the cooperative. Labor can be allocated to the fermentation process and the digestate processing process. For the fermentation process 85% of the labor is needed. For the digestate processing 15% is needed. 5% is needed for the reverse osmosis and 10% for the 80% d.m. digestate part. The total amount of hours needed per year for the complete installation is 3,744 hours (2 fte) based on 72 hours per week. The fee per hour is € 22.50.

Interest
The total interest cost for the complete installation are assumed to be € 138,600. This is based on an interest percentage of 3% of the financed amount of table 3.2. € 138,600 corresponds with 2.1% of the total investment. This low percentage is because only 70% of the total investment is financed. Only over this financed amount an interest percentage has to be calculated. So the interest amount can be calculated by taking 2.1% of the total investment.

Variable cost

Transport

The transport costs concern costs for supplying manure. For the supply of pig manure the transport cost are € 2.50 per ton. The farmer or bio fementation installation who removes manure or digestate pays a market price in which the distribution cost are calculated. So transport cost are included in the factor 'removal products'.

Supply co-products

For the fermentation process co-products are needed to enhance the gas yield. The co-products (maize, food waste and flower bulbs) have a weight of 12,150 tons and an average cost price of € 34 per ton.

Removal products

The removal cost consists of the removal of either the manure or the products that are a result from the operations at Biogreen. For manure the removal cost are € 23 (DCA Uden, 2008) per ton and for digestate € 18 because farmers are more willing to receive it due to its positive characteristics for crops. The same regulations as for animal manure go for RO concentrate. The price for the RO concentrate is also € 18 per ton. When it is accepted as an artificial fertilizer substitute then the price is expected to be € 5 per ton revenue. In this case for the RO concentrate there are specific transport cost which are € 3 per ton for the region of Salland and € 4 for Kampen and Veenkoloniën. This is including sampling cost. This cost factor will be mentioned under 'removal products'. The transportation to Germany will cost no money, but it will also not bring in any money. In the table below an overview of the products and their cost is shown.

Table 3.9 *Manure products with their removal and transport cost in € per ton.*

	Removal cost	Transport cost
Manure	-23	Included
Unprocessed digestate	-18	Included
Liquid digestate	-18	Included
RO concentrate as animal manure	-18	Included
RO concentrate as artificial fertilizer	+5	3-4

Water outlet

A rest product of Biogreen is water. This water can be expelled to the sewage which cost € 1 per ton. The intention is that in the future the produced water can be expelled to the surface water.

Electricity

All the electricity (15,552,000 kWh per year) produced by the heat power engines is sold as green energy to the public electricity network. In that case Biogreen receives subsidy about every produced kWh. The electricity needed for the process is bought from the 'gray' network. From this network Biogreen needs 5% of what it can produce. The ultra filtration and reverse osmosis part requires 80% of this amount the drying part 15% and the fermentation part 5%. The cost price for Biogreen for electricity is assumed to be € 0.11 per kWh on the basis of data of the CBS.

Maintenance

The maintenance differs from the kind of installation. Only fermentation means no cost for the decanter and UF/RO installation. The total yearly maintenance cost for the whole installation including UF and RO are € 220,000. For the decanters 5,000 is calculated and for UF/RO part € 35,000.

The impact of the discussed cost factors above are in some cases specific per scenario. Below in table 3.10 is shown which cost in which scenario plays a role. For some revenue or cost factors the amounts are standard values which apply for more scenarios. When nothing is mentioned for a cost or revenue factor this means this factor is not applicable for this scenario.

For some factors different units for the values are applicable. These are for all factors mentioned in the second column.

Table 3.10 *Revenue and cost factors per scenario where not indicated data are from Biogreen..*

		Unprocessed manure	Unprocessed digestate	80% d.m. digestate and liquid digestate	80% d.m. digestate and RO = AM	80% d.m. digestate and RO = AF
Revenues						
MEP	€		1,508,544	1,508,544	1,508,544	1,508,544
Electricity sales	€		1,306,368	1,306,368	1,306,368	1,306,368
Supply manure	€		774,900	774,900	774,900	774,900
RO concentrate sales	€					50,000
Fixed cost						
Investment	€		4,500,000	5,100,000	6,600,000	6,600,000
Labor	Fte		1.7	1.9	2	2
Interest	€		94,500	107,100	138,600	138,600
Variable cost						
Transport	€		123,188	123,188	123,188	123,188
Supply co-products	€		413,100	413,100	413,100	413,100
Removal products	€/ton	23[a]	18	18	18	3-4
Water outlet	€				28,750	28,750
Electricity	kWh		38,880[b]	116,640[b]	777,600[b]	777,600[b]
Maintenance	€		180,000	185,000	220,000	220,000

[a] DCA Uden, mestmarkt, November 2008.
[b] Derived from data CBS.

4 Results

4.1 Scenarios under basis situation

In this part the scenarios will be worked out one by one. These scenarios together are the ‘basis’ situation in paragraph 4.2 changing circumstances are elaborated. First the product distribution part of the scenario will be presented and afterwards the economical consequences. In the product distribution part the consequences with regard to the nutrients in the different regions will be worked out.

4.1.1 Unprocessed manure

In this ‘0’ scenario only the raw manure will be removed without any further processing. Because it is unprocessed manure no investment cost have to be made. In this scenario it can be assumed that Biogreen does not exists and all the cost for removing manure have to be paid by the farmers themselves.

Impact on nutrients

In the case the manure will not be processed by Biogreen an amount of 55,350 tons manure have to be removed. In table 3.1 the composition of the raw manure was shown. The composition in nutrients of this manure consists of 455 tons nitrogen and 277 tons phosphate.

Table 4.1 is the result from the calculation model from figure 3.2. To get a better overview differences in comparison with table 3.5 for supply and removal are shown. The other values are total numbers or percentages from total. So the differences are added up by the numbers from table 3.5. The data before supply and removal will not be included anymore in this and the next scenario tables. For Salland and Kampen the remaining capacities reduced for the level of acceptance for nitrogen are 0 after distribution. This means the total capacity for nitrogen for these regions is completely used (full). The line under the reduced capacity line in the table shows the total amount of manure that must be transported to that region. From table 4.1 it can be seen that for Salland and Kampen these quantities are almost the same and a smaller part has to go to Veenkoloniën.

Table 4.1 *Allocation of 55,350 tons raw manure without interference of Biogreen.*

Tons	**Salland**		**Kampen**		**Veenkoloniën**	
Nutrient balance	**N**	**P**	**N**	**P**	**N**	**P**
Supply Δ	0	0	187	114	87	53
Removal Δ	-180	-110	0	0	0	0
Usage	8,114	3,039	2,396	916	4,664	2,254
Remaining capacity	10	549	187	213	884	474
Degree of utility after transport	99.89%	84.70%	92.80%	81.13%	84.06%	82.62%
Remaining capacity corrected for acceptance level	0	516	0	50	496	263
Amount of manure	22,012		22,744		10,594	

Revenue/cost balance

The only cost in this scenario are the cost for the removal of the manure. This is including the cost for transport and dispersion on the land. There are no revenue receivings.

Table 4.2 *Cost division for 'unprocessed manure' without interference of Biogreen.*

Cost indicators	**Amount (€)**
Fixed cost	
Investment	-
Labor	-
Interest	-
Variable cost	
Transport	-
Supply co-products	-
Removal manure	1,273,050
Water outlet	-
Electricity	-
Maintenance	-
Total	**1,273,050**

4.1.2 Unprocessed digestate

This scenario concerns the situation when the manure of the farmers and co-products will be processed for energy. The rest product of this process is the digestate that has to be removed from Biogreen.

Impact on nutrients
In table 3.1 it seems to be clear that the content of the digestate consist of 7 kg nitrogen per ton and 3.4 kg phosphate. In the same way like the 'unprocessed manure' scenario first the region of Salland will be filled completely with the limiting nutrient nitrogen. Because of the different composition of digestate from manure and the different total amount the results for the distribution to the regions will differ. In this scenario the total amount of digestate is 60,750 tons which contains 425 tons of nitrogen and 207 tons of phosphate. In table 4.3 the exact consequences for the distribution to the regions are shown.

Table 4.3 *Division of ' unprocessed digestate' for Biogreen.*

tons	**Salland**		**Kampen**		**Veenkoloniën**	
Nutrient balance	**N**	**P**	**N**	**P**	**N**	**P**
Supply Δ	0	0	187	91	58	28
Removal Δ	-180	-88	0	0	0	0
Usage	8,114	3,017	2,396	893	4,635	2,229
Remaining capacity	10	571	187	236	913	499
Degree of utility after transport	99.88%	84.08%	92.78%	79.06%	83.55%	81.72%
Remaining capacity corrected for acceptance level	0	538	0	73	524	288
Amount of digestate	25,786		26,643		8,321	

Revenue/cost balance
In table 4.4 the revenue/cost division of the 'unprocessed digestate' scenario is shown. The subsidy receiving is a very big part on the revenue side. When diminishing the revenues with the cost factors the result are the earnings before taxes (*EBT*). EBT is a measure of the performance of a company. EBT is also called profit before taxes.

Table 4.4 *Revenue and cost division for 'unprocessed digestate' for Biogreen.*

	Amount (€)
Revenues	
Subsidy	1,508,544
Energy sales	1,306,368
Supply raw manure	774,900
Sales RO concentrate	-
Total	**3,589,812**
Cost	
Fixed cost	
Depreciation	450,000
Labor	71,604[1]
Interest	94,500
Subtotal	*616,104*
Variable cost	
Transport	123,188
Supply co-products	413,100
Removal digestate	1,093,500
Water outlet	-
Electricity	4,277
Maintenance	180,000
Subtotal	*1,814,065*
Total	**2,430,169**
EBT	**1,159,643**

[1] 85% of 3,744 hours (2 fte) * € 22.50

4.1.3 80% d.m. digestate and liquid digestate

In this scenario digestate is produced during the fermentation process and afterwards this digestate is processed by a decanter which results in a product with 30% dry matter. This product will be dried further till 80%. The liquid part which is over is liquid digestate this will not be processed further. In this case all unprocessed digestate has passed already the decanter. At Biogreen this option is not implemented.

Impact on nutrients
In table 3.1 the composition of the 52,750 tons liquid digestate was shown. The composition of the liquid digestate is the amount of nitrogen and phosphate of the unprocessed digestate diminished with the amounts in the 80% d.m. digestate. This results in the nitrogen and phosphate amounts of respectively 350 and 53 tons.

The 80% d.m. digestate will be distributed to Germany and the liquid fraction will be divided over the regions. In the nutrient balance below the exact allocation is shown.

Table 4.6 *Division of 'liquid digestate' processed by Biogreen.*

tons	**Salland**		**Kampen**		**Veenkoloniën**	
Nutrient balance	**N**	**P**	**N**	**P**	**N**	**P**
Supply Δ	0	0	170	26	0	0
Removal Δ	-180	-27	0	0	0	0
Usage	8,114	2,956	2,379	828	2,379	828
Remaining capacity	10	632	203	301	203	301
Degree of utility after transport	99.88%	82.39%	92.15%	73.31%	92.15%	73.31%
Remaining capacity corrected for acceptance level	0	599	16	138	16	138
Amount of digestate	27,138		25,612		0	

To see is that the balance for this scenario differs from the previous scenario. In this case it is not necessary to transport to Veenkoloniën and in Kampen there is remaining capacity left. This is because the total amount of manure is lower. The lower content of phosphate causes that the remaining capacity for phosphate in Salland and Kampen is much higher.

Revenue/cost balance
What the impact of this scenario of this nutrient balance is on the cost and revenue balance can be seen in table 4.7. The revenues part in the table is the same as in the previous scenario.

Table 4.7 *Revenue and cost division for '80% d.m. digestate and liquid digestate' for Biogreen.*

	Amount (€)
Revenues	
Subsidy	1,508,544
Energy sales	1,306,368
Supply raw manure	774,900
Sales RO concentrate	-
Total	**3,589,812**
Cost	
Fixed cost	
Depreciation	510,000
Labor	80,028
Interest	107,100
Subtotal	*697,128*
Variable cost	
Transport	123,188
Supply co-products	413,100
Removal digestate	949,500
Water outlet	-
Electricity	17,107
Maintenance	185,000
Subtotal	*1,687,895*
Total	**2,385,023**
EBT	**1,204,789**

Depreciation cost, labor cost, electricity and maintenance cost are higher in this scenario which makes the difference with the 'unprocessed digestate' scenario. However cost for removal are much lower which results in a more positive EBT.

4.1.4 80% d.m. digestate and RO concentrate as animal manure

In this scenario the RO concentrate will play a role. This product is produced at Biogreen together with the dry matter. The liquid part of the decanter will be produced further with the end result water and RO concentrate.

Impact on nutrients
In this scenario the dry matter product goes like before to Germany. The RO concentrate is the product which has to be allocated over the Dutch regions. There is only 10,000 tons of RO concentrate and 28,700 tons expellable water. The composition can be found in table 3.1 which gives a total amount of 68 tons of nitrogen and only 6 tons of phosphate. Table 4.8 shows which impact the allocation of this product on the nutrient balance of the regions.

Table 4.8 *Division over the regions RO concentrate processed by Biogreen in tons.*

Tons	Salland		Kampen		Veenkoloniën	
Nutrient balance	**N**	**P**	**N**	**P**	**N**	**P**
Supply Δ	0	0	0	0	0	0
Removal Δ	-68	-6	0	0	0	0
Usage	8,001	2,935	2,209	8902	4,577	2,201
Remaining capacity	122	653	373	327	971	527
Degree of utility after transport	98.50%	81.80%	85.55%	71.04%	82.50%	80.68%
Remaining capacity corrected for acceptance level	113	620	187	164	583	316
Amount of RO concentrate	10,000		0		0	

Because of the small volume of the RO concentrate everything can stay in Salland where even capacity is left over.

Revenue/cost balance

The nutrient balance for the regions has the following consequences for the revenues and cost to be seen in table 4.9.

Table 4.9 *Revenue and cost division for '80% d.m. digestate and RO as animal manure' for Biogreen.*

	Amount (€)
Revenues	
Subsidy	1,508,544
Energy sales	1,306,368
Supply raw manure	774,900
Sales RO concentrate	-
Total	**3,589,812**
Cost	
Fixed cost	
Depreciation	660,000
Labor	84,240
Interest	138,600
Subtotal	*882,840*
Variable cost	
Transport	123,188
Removal RO concentrate	180,000
Supply co-products	413,100
Water outlet	28,750
Electricity	85,536
Maintenance	220,000
Subtotal	*1,050,574*
Total	**1,933,414**
EBT	**1,656,398**

In this scenario labor and electricity cost are at the highest level. The removal cost are quite lower due to the low volume of RO concentrate. The complete installation is working and all the labor is used. A new revenue is the cost for removing the water to the sewage.

4.1.5 Dry matter and RO concentrate as artificial fertilizer

In this last scenario the technical process is the same as in the previous scenario. That is why the nutrient balance for the regions is not shown. The only difference in this case is that for the RO concentrate the same usage norms apply as for artificial fertilizer. In practice only for nitrogen the norms are higher and more RO concentrate is allowed to be dispersed per hectare. In the previous scenario it was already made clear that there is enough capacity in Salland to allocate all the RO concentrate in that region. In this case when the norms are wider this will be of course the same. In table 4.10 the revenue and cost factors are shown. The difference in the revenues is that the RO concentrate brings in money because it is accepted as artificial fertilizer. In the cost factor there are no removal cost, but Biogreen has to pay transport cost. In this case it concerns only transport within Salland.

Table 4.10 *Revenue and cost division for '80% d.m. digestate and RO as artificial fertilizer' for Biogreen*.

	Amount (€)
Revenues	
Subsidy	1,508,544
Energy sales	1,306,368
Supply raw manure	774,900
Sales RO concentrate	50,000
Total	**3,639,812**
Cost	
Fixed cost	
Depreciation	660,000
Labor	84,240
Interest	138,600
Subtotal	*882,840*
Variable cost	
Transport	123,188
Supply co-products	413,100
Removal products[1]	58,750
Electricity	85,536
Maintenance	220,000
Subtotal	*900,574*
Total	**1,783,414**
EBT	**1,856,398**

[1] Contains water outlet and transport RO concentrate

4.1.6 Overview

In the table below an overview of all the scenarios is given with their revenues and costs. It can be seen that the fermentation process generates revenues which are able to cover the cost. Because of the environmental consequences production of a surplus of manure causes only costs. All scenarios make clear that it can be profitable to process the manure and give value to it. The last 2 scenarios which concern the RO concentrate show that these are the most attractive options because of less cost for removal of products and possible receivings for the end product; the RO concentrate when accepted as artificial fertilizer.

In table 4.11 besides the overview of revenues and costs is shown per scenario. In the same table the EBT values for the scenarios are shown as well. To see is that the EBT values increase per scenario. When EBT is divided by the revenues the result is the *profit margin*. This can be useful to compare the profitability of the activities between different scenarios. The scenario when the RO concentrate can be used as artificial fertilizer shows the highest margin. The fact that Biogreen is striving for this option seems to be the most logical.

Table 4.11 *Overview of revenue and cost factors of 'basis' situation.*

	Unprocessed manure	Unprocessed digestate	80% d.m. digestate and liquid digestate	80% d.m. digestate and RO = AM	80% d.m. digestate and RO = AF
Revenues					
Subsidy	-	1,508,544	1,508,544	1,508,544	1,508,544
Energy sales	-	1,306,368	1,306,368	1,306,368	1,306,368
Supply raw manure	-	774,900	774,900	774,900	774,900
Sales RO concentrate	-				50,000
Total	**0**	**3,589,812**	**3,589,812**	**3,589,812**	**3,639,812**
Cost					
Fixed cost					
Depreciation	-	450,000	510,000	660,000	660,000
Labor	-	71,604	80,028	84,240	84,240
Interest	-	94,500	107,100	138,600	138,600
Subtotal	*0*	*616,104*	*697,128*	*882,840*	*882,840*
Variable cost					
Transport	-	123,188	123,188	123,188	123,188
Supply co-products	-	413,100	413,100	413,100	413,100
Removal manure/ digestate/water/RO	1,273,050	1,093,500	949,500	208,750	58,750
Electricity	-	4,277	17,107	85,536	85,536
Maintenance	-	180,000	185,000	220,000	220,000
Subtotal	*1,273,050*	*1,814,065*	*1,687,895*	*1,050,574*	*900,574*
Total	**1,273,050**	**2,430,169**	**2,385,023**	**1,933,414**	**1,783,414**
EBT	**-1,273,050**	**1,159,643**	**1,204,789**	**1,656,398**	**1,856,398**
Profit margin	**-**	**0.32**	**0.34**	**0.46**	**0.51**

4.2 Changing circumstances

In the paragraph above the nutrient balances and revenues and costs balances were calculated per scenario. However it can also be interesting to investigate possibilities when some external factors change. For the same scenarios can the revenues and cost be calculated in a situation when 1 or more external factors change. The scenarios stay the same, but they will be calculated for 3 new *circumstances*. The manure scenario will be left out the tables because this will not change. At the end it is interesting to compare the EBT of the same scenarios for different circumstances. To be clear: these changing circumstances will have no effect on the distribution across the regions. From now on in all tables the profit margins are shown as well. In this paragraph the following changing circumstances will be elaborated in an analysis:

- Without MEP subsidy
- Building on a new location
- New location with SDE subsidy

4.2.1 Without MEP subsidy

In this situation the financial consequences are calculated when Biogreen does not receive any MEP subsidy. What the consequences for this will be for the different scenarios is to see in table 4.12. No MEP subsidy has only a consequence for the revenue side, the cost factors stay the same as in the previous paragraph.

Table 4.12 *Overview of revenues of all scenarios of Biogreen in euro per year without subsidy*.

	Unprocessed digestate	80% d.m. digestate and liquid digestate	80% d.m. digestate and RO = AM	80% d.m. digestate and RO = AF
Revenues				
Subsidy	0	0	0	0
Energy sales	1,306,368	1,306,368	1,306,368	1,306,368
Supply raw manure	774,900	774,900	774,900	774,900
Sales RO concentrate				50,000
Total	**2,081,268**	**2,081,268**	**2,081,268**	**2,131,268**
Cost	**2,430,169**	**2,385,023**	**1,933,414**	**1,783,414**
EBT	**-348,901**	**-303,755**	**147,854**	**347,854**
Profit margin	**-0.17**	**-0.15**	**0.07**	**0.16**

When looking at the EBT and profit margin it can be seen that values are much lower. The profitability is even negative in the first 2 scenarios and slightly positive in the scenarios with RO production.

4.2.2 Building on a new location

In this situation the opportunity is investigated when an installation like Biogreen would be built completely new on industrial terrain and use an external manager. In the basis situation Biogreen could build on terrain of a contract worker where also some storage silos can be used. When a similar installation would be built on a new location 2 hectares of land have to be available. Because of the big size of the installation it has to be built on industrial area. The price for industrial is estimated at € 250,000 per hectare. With an interest percentage of 3% per year. The rent cost per hectare will be € 7,500 per year. Further, 3 silos of 50 m^3 each (1,500 m^3) have to be built for extra storage of co-products. These will cost € 50 per m^3. Also an external manager of € 80,000 (1 fte) have to be attracted. The cost price for this manager is based on his responsibilities. He heads for the employees, he does purchases and he has the responsibility for the budget. This situation only have impact on the fixed cost side which is shown in table 4.13. Which consequences this have on the EBT and profit margin is also shown.

Table 4.13 *Financial overview of all scenarios in case of building new in euro per year*.

	Unprocessed digestate	80% d.m. digestate and liquid digestate	80% d.m. digestate and RO =AM	80% d.m. digestate and RO = AF
Cost				
Fixed cost				
Depreciation	457,500	517,500	667,500	667,500
Labor	151,604	160,028	164,240	164,240
Interest	109,500	122,100	153,600	153,600
Subtotal	*718,604*	*799,628*	*985,340*	*985,340*
Variable cost				
Subtotal	*1,814,065*	*1,687,895*	*1,050,574*	*900,574*
Total	**2,532,669**	**2,487,523**	**2,035,914**	**1,885,914**
Revenues	**3,589,812**	**3,589,812**	**3,589,812**	**3,639,812**
Cost	**2,532,669**	**2,487,523**	**2,035,914**	**1,885,914**
EBT	**1,057,143**	**1,102,289**	**1,553,898**	**1,753,898**
Profit margin	**0.29**	**0.31**	**0.43**	**0.48**

In the situation of building on a new location the profit margins are still positive, but a little lower than in the basis situation because higher cost are not compensated by more revenues.

4.2.3 New location with SDE subsidy

In this situation the subsidy which Biogreen receives is replaced by the current SDE subsidy. This means that the subsidy consists of the gap between the subsidy upper limit of € 0.12 per kWh and the actual electricity price. At this moment the electricity price is € 0.084 per kWh. So € 0.036 is the subsidy amount per kWh. In this situation this subsidy will be calculated for the different scenarios including the situation in the previous paragraph. This situation is the most realistic for installations which are going to be built at this moment.

In table 4.14 the financial results for this changing circumstance are shown. Only the revenues will be shown. The cost factors stay the same as in table 4.13.

Table 4.14 *Financial overview of all scenarios in case of building new and with SDE in euro per year.*

	Unprocessed digestate	80% d.m. digestate and liquid digestate	80% d.m. digestate and RO = AM	80% d.m. digestate and RO = AF
Revenues				
Subsidy	559,872	559,872	559,872	559,872
Energy sales	1,306,368	1,306,368	1,306,368	1,306,368
Supply raw manure	651,713	651,713	651,713	651,713
Sales RO concentrate				50,000
Total	**2,517,953**	**2,517,953**	**2,517,953**	**2,567,953**
Cost	**2,532,669**	**2,487,523**	**2,035,914**	**1,885,914**
EBT	**-14,716**	**30,430**	**482,039**	**682,039**
Profit margin	**-0.01**	**0.01**	**0.19**	**0.27**

To see is that in this situation the profit margins are all positive. Of course they are less positive than in the previous situation because of the new subsidy which is lower. But it is clear that building new and receiving subsidy can be profitable for this kind of installations. Receiving no subsidy at all means in the case of building on a new location that only the last scenario shows a positive profit margin.

4.2.4 Impact changing circumstances

In this paragraph an overview of the 3 changing circumstance is shown as well as the basis situation. With this overview it is possible to make a comparison between both the scenarios and the different changing circumstances described in the previous paragraphs. The basis situation means the current situation of Biogreen.

Table 4.15 *Overview of the basis and 3 new changing circumstances for all the scenarios.*

	Unprocessed digestate	80% d.m. digestate and liquid digestate	80% d.m. digestate and RO = AM	80% d.m. digestate and RO = AF
Basis situation				
Revenues	3,589,812	3,589,812	3,589,812	3,639,812
Cost	2,430,169	2,385,023	1,933,414	1,783,414
EBT	1,159,643	1,204,789	1,656,398	1,856,398
Profit margin	0.32	0.34	0.46	0.51
Without MEP				
Revenues	2,081,268	2,081,268	2,081,268	2,131,268
Cost	2,430,169	2,385,023	1,933,414	1,783,414
EBT	-348,901	-303,755	147,854	347,854
Profit margin	-0.17	-0.15	0.07	0.16
Building on new location				
Revenues	3,589,812	3,589,812	3,589,812	3,639,812
Cost	2,532,669	2,487,523	2,035,914	1,885,914
EBT	1,057,143	1,102,289	1,553,898	1,753,898
Profit margin	0.29	0.31	0.43	0.48
New with SDE subsidy				
Revenues	2,517,953	2,517,953	2,517,953	2,567,953
Cost	2,532,669	2,487,523	2,038,186	1,885,914
EBT	-14,716	30,430	479,767	682,039
Profit margin	-0.01	0.01	0.19	0.26

5 Conclusion and discussion

5.1 Conclusion

In this part some conclusions are drawn for this study. The conclusions are drawn per objective.

5.1.1 The 'digestate context'

During the first objective the 'digestate context' was elaborated for a number of topics. It was made clear that digestate is a result from manure fermentation including fermentated co-products. This digestate is the basis for further processing it by different techniques. The nutrients from the manure and co-products stay in the digestate, but change partly from an organic to a more mineral form which makes that they can easier and more instantly be taken up by plants.

The policy around digestate is the same as for manure. The Manure law contains the details from this policy. For the nutrients nitrate and phosphate norms apply how many kilogram nutrients may be dispersed on a hectare.

For farmers who want to remove their animal manure they have to pay a market price due to the manure surplus. As the policy around digestate is the same as for manure also digestate is 'economically' considered as manure. Because the nutrients of the co-products increase the total quantity of nutrients in the digestate it enlarges the regional nutrient surplus. For farmers this market price is a big share in their total business costs and is a reason to search for ways to restrict this cost factor. At the Biogreen installation they are struggling for this manure problem and its accompanying cost with giving value to the digestate by processing it further with different techniques.

No studies were found with the emphasis on digestate processing with a scenario analysis. Studies were found about regional projects with bio products. The focus point digestate concerned a small part of the studies.

5.1.2 Scenario analysis

Basis situation

This study concerns 4 digestate scenarios. Compared with a '0' scenario of 'unprocessed manure' ('doing nothing') it became clear that processing the manure and give value to it is more profitable as 'doing nothing' only cost money for farmers. Farmers get money back when Biogreen is making profit.

The scenarios show that land capacity of all regions is needed in the 'unprocessed digestate' scenario. This because of the big amount of digestate in that scenario. In the 80% d.m. and liquid digestate scenario capacity from just 2 regions is needed because a big amount of nutrients is exported in a fixed fraction. In the scenarios with RO concentrate production the region of Salland fulfills because a lot of expellable water is filtered due to the ultra filtration and reverse osmosis techniques. These scenarios seem to be a sustainable solution for the regional manure surplus.

Looking at the basis situation financially it can be concluded that subsidy is an important revenue factor. The scenarios with RO concentrate production show the highest profit margins. The striving of Biogreen for getting RO concentrate accepted as artificial fertilizer substitute is also financially the best option. The results in the scenarios also show that the lower getting removal cost influence the profit margin more than the higher getting processing cost. The mean reason of the decreasing total cost are the decreasing removal cost.

Changing circumstances
When no MEP subsidy is allotted this will result in a huge fall of the profit margin. Building on a new location brings extra cost, but the profit margin decrease stays relatively small. The situation of building new including SDE subsidy is the most realistic one. It shows a small negative profit margin for the 'unprocessed digestate' scenario. This means that new installation with the characteristics of Biogreen that plan to do only manure and co-fermentation this is given the actual SDE subsidy not profitable. To be financially successful with the characteristics of Biogreen it is necessary to give worth to the digestate with different processing techniques.

Table 5.1 *Product Digestate/RO concentrate distribution and cost/revenue balance for basis and changing circumstances per scenario*.

		Unprocessed digestate	80% d.m. digestate and liquid digestate	80% d.m. digestate and RO as animal manure	80% d.m. digestate and RO as artificial fertilizer
BASIS SITUATION	*x1,000 tons*				
Digestate/RO distribution					
Salland		26	27	10	10
Kampen		27	26	-	-
Veenkoloniën		8	-	-	
Germany (export)			8	8	8
Total		61	61	18	18
Revenues	*x € 1,000*				
Subsidy		1,509	1,509	1,509	1,509
Energy sales		1,306	1,306	1,306	1,306
Supply raw manure		775	775	775	775
Sales RO concentrate					50
Total revenues		**3,590**	**3,590**	**3,590**	**3,640**
Fixed cost					
Depreciation		450	510	660	660
Labor		72	80	84	84
Interest		95	107	139	139
Subtotal		*617*	*697*	*883*	*883*
Variable cost					
Transport		123	123	123	123
Supply co-products		413	413	413	413
Removal manure/ digestate/water/RO		1,094	950	209	59
Electricity		4	17	86	86
Maintenance		180	185	220	220
Subtotal		*1,814*	*1,688*	*1,051*	*901*
Total cost		**2,431**	**2,385**	**1,934**	**1,784**
Earnings before taxes		1,159	1,205	1,656	1,856
Profit margin		**0.32**	**0.34**	**0.46**	**0.51**
PROFIT MARGINS FOR CHANGING CIRCUMSTANCES					
Without MEP		-0.17	-0.15	0.07	0.16
Building on new location		0.29	0.31	0.43	0.48
New with SDE subsidy		-0.01	0.01	0.19	0.26

5.2 Discussion

In this part an explanation for the method choice will be given as well as some shortcomings from this study in general.

Data

The Biogreen numbers including financial numbers have been acquired by interviews at the installation site. Especially the financial numbers can be some uncertain in the scenarios which are not practiced at Biogreen. For example for ‘electricity’ and ‘labor’ is worked with fractions as percentages of total usage of the installation. This can be some subjective, but because they are supplied by Biogreen they are satisfying. Also some numbers had to be assumed. The levels of acceptance are coming from literature in the case of raw manure. Levels of acceptance are quite subjective and differ per farmer, per region et cetera. For (liquid) digestate and RO concentrate these numbers are not known but in this research for RO concentrate they are assumed to be higher for the different regions. It is possible that assumptions can somewhat distort the reality. However for the presented results making assumptions should not influence the conclusions significantly.

For the revenue/cost statement the data made it possible to calculate the earnings before taxes. For some factors assumptions has to be made to make all the data complete for all the scenarios. Besides of that, for making the financial analysis the revenues and cost are compared before taxes and other costs like accountant, insurance and bank costs. So in practice more costs show up which have their impact on the financial result.

For the input side of the installation all the scenarios take the same input into account. However in practice the input of the co-material can change. This depends on prices and availability. So input prices change, but also the composition of the output material can change. However because it is in all scenarios the same they can be compared reliable.

Because in this study the Biogreen case has been studied only conclusions about this installation can be made or installations with the same characteristics. This can make the results some restricted.

Choice of scenarios

In the research 4 scenarios have been chosen for. The ‘unprocessed manure’ scenario only had 1 cost factor. However it is very meaningful to compare this ‘0’ scenario with the digestate processing scenarios. Since it was clear that all scenarios show more positive results than the ‘unprocessed manure’ scenario it became interesting to compare with the other scenarios. The ‘unprocessed digestate’ and the ‘80% d.m. digestate and liquid digestate’ scenario are theoretical because at Biogreen these scenarios are not conducted. These scenarios are chosen because there are other installations where only fermentation takes place or only drying after fermentation. Showing these scenarios makes also the values more meaningful because they can be compared with the outcomes of other scenarios. Another reason is that is shown now what the results are when Biogreen will quit with ultra filtration and reverse osmosis. The last scenario is chosen because that is the ultimate aim of Biogreen. The RO concentrate has to be accepted as green fertilizer to make real profit with the project.

Literature reflection
This study is basically focused on a practical case. As a consequence of this the outcomes of this study are also quite case specific as well as the input factors for the scenario analysis. Because of that, comparison with other installation from literature is for this study difficult and not always confidential and suitable. The literature part in this study concerns other studies with bio products on a regional scale. Although some studies concern digestate projects these are not very suitable to compare with the case in this study. They concern different focus points of regional studies. The fact that no studies were included about digestate processing with ultra filtration and reverse osmosis proves that these are very scarce. However when elaborating the first objective of this study literature played an important role but in this part the costs of ultra filtration and reverse osmosis were also mentioned. For the Biogreen case it is difficult to compare with these numbers because the quick-scan figures from literature did not make clear which cost exactly were taken into account.

5.3 Recommendations

Based on the findings in this study some recommendations can be made.

Policy
The financial results seem to be quite positive for the scenario with RO concentrate as artificial fertilizer. However the effect of RO concentrate on arable land and crops is not yet known in detail. Giving permission to implement pilot projects is already a very good starting point to get RO concentrate accepted as artificial fertilizer.

Another issue that is already on the agenda of the Dutch government is the debate about the height of the SDE subsidy. At the moment the subsidy is paid until € 0.12 per kWh. For Biogreen this subsidy will result in a positive result when RO concentrate is produced. However most farmers only build a manure fermentation installation without further processing. For those entrepreneurs such an investment would not be profitable with the SDE subsidy according to this research and the characteristics of Biogreen. In case the government want to stimulate bio fermentation this subsidy have to be raised. With only € 0.01 per kWh extra subsidy a positive margin will be reached.

Sector
Projects like Biogreen are initiatives to withstand the manure problem. For farmers in especially the manure concentration areas like the province of Brabant and the northern part of Limburg these kinds of projects can be interesting developments for them. Working in a cooperative form is a very stable and good way to setting up projects like Biogreen. But it will only work once the members all have the same ideas. At the moment there are just a few installations who process digestate from manure with ultra filtration and reverse osmosis. Because of the uncertainty of getting the RO concentrate being accepted as substitute for artificial fertilizer it is imaginable that not many other farmers' projects are developed. However a role for farmers organizations is that they farmers inform about the potential possibilities and the advantages that could be reached with it, financially for their farms and for the society.

When in the future RO concentrate is possibly accepted as artificial fertilizer substitute the price of it can be lower than that of artificial fertilizer. Artificial fertilizer is expected to be more expensive the coming years. In case of big-scale RO concentrate production a living trade in this can show up with decreasing prices. To reach this also Biogreen itself has to be open to show their activities and let people do research to the installation and publish it to get more insight in it.

Also for publicists of agricultural newspapers and journals there is a role. They have to inform farmers objectively about these kinds of possibilities and may stimulate them to think about similar projects themselves. Besides of that they will inform the whole society that sustainable projects in agriculture are developed and will give the Dutch agriculture a better image.

5.4 Further research

After this research it would be advisable to do some other (related) research.

Digestate and especially RO concentrate is not used on very big scale in The Netherlands. A possibility for further research can be to study the willingness of farmers to accept these products on their land. Do they really prefer it more than raw manure and does the price play a role? In this case accurate levels of acceptance can be composed.

The focus was not really on the products UF concentrate and 80% d.m. digestate. Because it went back in the system and was exported to Germany respectively. But it could be investigated whether there are other alternatives for these products in for example The Netherlands.

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