Economic and institutional aspects of biogas production

MSc Thesis Agricultural Economics and Rural Policy

Jaap Sok

February 2012

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Preface and acknowledgements

"A goal is a dream with a deadline." **– Napoleon Hill**

After some failing attempts, this time biogas production has had its breakthrough in The Netherlands. In fulfilling the EU and national *goals* set for reducing greenhouse gas emissions and the need to become less dependent on fossil fuel energy sources, in the Dutch agricultural sector, with the catalysing effect of government support, multiple projects have been realised producing biogas for renewable energy production, mainly using co-digestion of manure techniques.

But, new biogas initiatives in the agricultural sector decline and *deadlines* indicating when those *goals* have to be fulfilled are coming closer. Luckily, other initiatives still come up but they use other sources and techniques.

The Current Dutch Minister for Agriculture has another *dream*: reform the manure market to anticipate on future expected developments. Among others, manure processing is seen as a way solving the current excess manure problem and anticipating on estimated future mineral shortages.

What about those *dreams* and *goals*?

My master programme almost ends; my own *dream* has almost become real with the realisation of this research. I would thank my supervisor dr.ir. Peerlings for the nice and stimulating conversations and the supervision I gained from him for this research.

My thoughts and appreciation go to my dear parents who gave me the opportunity to study and thereby their supportive role and interest in my work. And to Hanne for her tender care and motivation before and since we have been together. Lastly and most important, my gratitude is expressed to my Creator. 'The fear of the Lord is the beginning of knowledge, but fools despise wisdom and instruction' (Proverbs 1: 7).

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February 2012

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Executive summary

Biogas is produced out of organic materials in an oxygen-free environment. The growth of biogas production in The Netherlands is mainly caused by co-digestion of manure. Obtained biogas is mainly utilized for producing renewable electricity. The outcome of a stakeholder analysis revealed that before construction of a plant, nearly all stakeholders, both public and private, preferably should co-operate to prevent future failures, like NIMBY behaviour of neighbours. Economic and institutional factors were identified affecting the success of the current biogas sector. Among others, the high uncertain environment is a main concern. Another issue is the high transaction specific investments made for biogas production. Also some market failures have been identified which possibly justifies government intervention. We identified a missing common vision how to operate and a public concern touching upon the ethical aspects of biogas production. Therefore, a more specified governance structure is preferred due to the complex environment for the decision-maker (bounded rationality notion) and the threat of opportunistic behaviour of other actors. More specifically, a hybrid governance structure is preferred due to the high uncertainties present, the substantial transaction-specific assets and low frequency rate of transactions.

The outcome of the case study revealed that high uncertainties were existing, especially regarding government policies, markets for high energetic biomass and techniques used. Looking at the transaction-specific assets, different forms of asset specificity were present. For some of them there was a solution, for other no solution was present leading to negative financial consequences. Found results hitherto gave rise to discuss two new developments coming up: new subsidy programme (SDE+) for renewable energy production and ideas proposed for reforming the existing manure policies. As a consequence of the new subsidy programme design, competition and budget ceiling, large biogas projects apply for subsidization using valuable high energetic biomass owned by the investors. Co-digestion of manure projects cannot compete against these large projects for a subsidy. For current co-digestion of manure plants, high energetic biomass inputs will become less available and therefore further weaken the financial feasibility. Regarding the second development, when suggested manure policy reforms will become real, in the intermediate run it is expected that this will have a positive effect on the financial feasibility of biogas plants using co-digestion of manure. In the long run, when it is assumed that gate fees further decline, the effect of lower gate fees outweighs the increasing sales opportunities for the digestate and finally give lower financial results.

Chapter 1: Introduction

1.1 Background

The attention for biogas production in the Netherlands has been going up and down over the last decades for different reasons. In the 1980s, biogas production was seen as a possible solution to reduce odour nuisance from manure and the existing oil shortages during that time gave an extra impulse. But a decline in oil prices and more oil supply certainty, technical failures and complicated permit regulations stopped the developments of biogas plants (Negro *et al.*, 2007). Biogas production and use is not something which can only be found in Europe. For example, there are a lot of (poor) countries in which people have their own small scale biogas plant. The obtained biogas is e.g. used to cook.

Almost all stakeholders are convinced that biogas production can contribute to an economy which is more 'future-proof'. It can be placed into the context of a bio-based economy. The (world)economy is heavily dependent on fossil fuels of which prices are increasing. The idea of a bio-based economy is to become less dependent from fossil fuels and on top, it will lead to a reduction of greenhouse gas emissions. Therefore, ambitious goals are set for renewable energy production and greenhouse gas emission reductions (European Union, 2009; Ministerie van Landbouw *et al*., 2007). Within Europe there have been many initiatives introduced to use biogas at middle or large scale. Similarly, the production of biogas in The Netherlands has increased substantially since 2005. In 2009, four years later, total energy produced with biogas plants had doubled. This was mainly initiated by an increase of co-digestion of manure project realizations (CBS Statline, 2011). Using anaerobic digestion processes, manure is digested to obtain biogas. Co-digestion of manure implies that other high energetic biomass, is added in order to get higher methane yields. As the growth of the Dutch biogas sector is mainly caused by co-digestion of manure, we will concentrate upon that particular system.

Despite this spectacular growth in absolute terms, the use of biogas in The Netherlands is weakly developed in comparison with other countries like Germany, Denmark or Sweden. In the Dutch agricultural sector at this moment, almost 100 farmers have invested in a biogas plant, of which 50 per cent was not profitable in the last two years (Boerderij, 2011a; Trouw, 2011; Peene *et al.*, 2011). Several biogas plants have even gone bankrupt for a number of reasons (Boerderij, 2011a; Peene *et al.*, 2011). Two reasons for these weak performances are the price volatility of inputs and the bad sales opportunities of digested manure (an output). Consequently, there is uncertainty about the existence of good-quality affordable inputs and possibilities to sell outputs making the activities profitable. In addition to the uncertainty issue, there is the occurrence of high asset specificity. Once a biogas plant has been installed and a big investment is made it is almost impossible to switch to another economic activity in case of weak financial performance. Possibly this leads to lock-in or hold-up problems (see for a discussion Slangen *et al.*, 2008). There is further the problem of high transaction costs when starting up a biogas plant. These elements – uncertainty, asset specificity and transaction costs – form three of the criteria to determine which organizational form is preferred for biogas plants (Bijman, 2002).

The economic profitability of biogas plants at this moment thus is low. Biogas plants are still in a process of technological development, they are not fully matured. The full potential is not met. One solution to make biogas plants more profitable is to improve or extend the production techniques making the plants more efficient. An example is to use the heat of the production process for other purposes, e.g. heating of houses. These upgraded technologies often are available but the introduction is prevented due to uncertainty of regulations (Gebrezgabher *et al.*, 2010). This time-inconsistency makes it for a researcher or policy maker difficult to determine in which stage biogas production nowadays technologically is.

Summarizing, besides the issue of technology, economic and institutional factors play a role in the success of biogas plants (e.g. Negro *et al.*, 2007; Peerlings, 2009). Factors like government policies, prices of inputs and outputs and information asymmetries between players in the biogas supply chain determine a substantial part of the success of biogas production. A well-developed production technique making biogas (and possible other valuable end products) is of no use without the existence of a good institutional and economic setting. Regarding the latter case for example, the way in which transactions are organized (e.g. input of manure in a biogas plant) matters (Altman and Johnson, 2008). Transaction cost theory shows three types of possible governance structures: the price mechanism, vertical integration and a hybrid structure, like contract farming or a cooperative.

The current economic and institutional environment for biogas production needs to be analysed to identify obstacles for implementation. Should the market mechanism do its work? Or is government intervention needed? What is the best governance structure? As biogas production is relevant in the context of a bio-based economy, its adoption is also a public concern.

1.2 Research Objective and Questions

The objective of this research is to identify the economic and institutional factors affecting the economic profitability of biogas production in the Netherlands.

In this research we focus on economic and institutional factors of biogas production. Technological factors are outside the scope of this study. Furthermore, most of the biogas at this moment is produced in the agricultural sector, using co-digestion of manure techniques. As a result, most answers to the research questions will be constrained to the biogas activities done in the agricultural sector.

In order to give a well-structured and underpinned answer to the objective of the research, the following research questions have to be answered:

1. *How does biogas production work and what different methods have been applied in the Netherlands?*

   As a first step, we should get an image of the biogas production techniques and its different applications in the Dutch biogas sector. This is necessary to determine which economic and institutional factors affect the performance of the biogas production sector.

2. *Which stakeholders play a role in the biogas production sector?*

   An economic and institutional analysis requires knowledge on which stakeholders are involved in the production and use of biogas.

3. *Which economic and institutional factors play a role in biogas production in the Netherlands?*

   Several feasibility studies (Courage and InnovatieNetwerk, 2007; Meijer *et al.*, 2008; Wilt and Boosten, 2011) have been carried out to identify the challenges for improving the economic feasibility of biogas production and use. Different stakeholders were incorporated in these studies. The feasibility studies can be used as a starting point for creating a list of potential economic and institutional factors affecting the biogas production.

4. *According to economic and institutional theory, what would theoretically be the best governance structure for a biogas supply chain?*

   It is useful to apply transaction cost theory as a way to explain which governance structure is best suited for actors in the biogas supply chain. The governance structures used in the Dutch biogas supply chain will be compared with governance structures as described in theory.

5. *Which factors are an obstacle for the success of biogas production in the Netherlands?*
   By means of a case study the economic and institutional factors indicated in the outcome of question 3 can be empirically analysed. The case study object is a relatively large biogas plant in The Netherlands which has been the subject of different studies (Gebrezgabher *et al.*, 2010; Van der Werf, 2010; Velthof, 2011).

   Finally, we discuss two new developments: the implications of the renewed subsidy programme (SDE+) and the ideas proposed by the Dutch minister of Agriculture to reform the manure policies. For the latter, some scenarios are formulated respresenting current and expected future circumstances due to changing manure policies. These scenarios will be simulated using an economic model. The LP-model of Gebrezgabher *et al.* (2010) has been used for this. Both developments could have an economic impact on existing biogas plants, especially those which have adopted the co-digestion of manure techniques.

1.3 Methodology

Given the different research questions, different methodologies will be used. The main method is literature research. Economic and institutional theories will be applied to describe or assess certain phenomena.

One way of getting information will be to interview an important actor in the field. The interviewee is the former owner of the Biogreen biogas plant, which was a cooperative of 50 swine farmers. This will help to get a better understanding of what is going on in the biogas production sector in the Netherlands.

An existing economic model of a biogas plant operation is used that can help to analyse the performance of the biogas production sector when all kinds of changes occur, like the implications of new policies. In this research, scenarios are formulated to simulate possible future outcomes of manure policy reforms. The model worked with is a mathematical programming model developed by Gebrezgabher *et al.* (2010).

1.4 Overview report

The structure of the report will be as follows: chapter 1 forms the introduction. In chapter 2 we answer the first research question, relating to biogas production. Then in chapter 3 a stakeholder analysis is performed to get an answer for the second research question. In chapter 4 we asses economic and institutional factors affecting the feasibility of the biogas sector in The Netherlands, in answer to the third research question. Then in chapter 5 a transaction cost economics (TCE) analysis is used to determine the right governance structure for the biogas supply chain. This will give us an answer to the fourth research question. The final research question is the subject of analysis in both chapter 6 and 7. In chapter 6, a case study is used to find empirical evidence for the economic and institutional factors found in previous chapter. In chapter 7, two recent developments, the SDE+ subsidy programme and new manure policies, are studied. Finally, chapter 8 forms the conclusions and discussion section wherein we evaluate whether the research objective has been realised. Additionally, two appendices are included. The first one is the interview with the former owner of Biogreen. The second appendix contains a basic description of the LP-model used. Extra information about this model can be found in Gebrezgabher *et al.* (2010).

Chapter 2: Biogas production

The production and use of biogas is not something new. The anaerobic digestion technique to make biogas out of organic material is applied all over the whole world. For example, in many developing countries people have their own small-scale biogas plant running on excreta, urine and kitchen waste. The obtained biogas is used to cook. In more technologically advanced countries, biogas production is used on a larger scale. In those countries, biogas production and use is seen as a way to become less dependent on fossil fuels. Another reason is that biogas production directly can lead to less greenhouse gas emissions by capturing methane (21 times more harmful greenhouse gas than carbon dioxide) for biogas utilization. An indirect effect is that other environmental unfriendly energy sources are avoided (linked with first reason). Within Europe there have been many initiatives introduced to use biogas at medium or large scale.

In this chapter we will answer the first research question: How does biogas production work, what different sources are used and how is it utilized in The Netherlands? In section 2.1 the biogas composition and production are described. In section 2.2 some basic environmental factors affecting biogas production are summed up. In section 2.3, we look to different sources of biogas in The Netherlands, out of which today biogas from co-digestion of manure is most adopted. Section 2.4 explains the characteristics of the digested organic materials, called digestate. Section 2.5 describes the utilizations of biogas. Section 2.6 concludes this chapter.

2.1 Biogas composition and production

Biogas consists mainly of a mixture of methane (CH_4) and carbon dioxide (CO_2). The gas is a result of an anaerobic[1] digestion process: ‘a process in which micro-organisms derive energy and grow by metabolizing organic material in an oxygen-free environment resulting in the production of methane’ (Reith *et al.*, 2003). For a good anaerobic digestion process, the biomass inputs should contain carbohydrates, proteins, fats, cellulose and hemicelluloses. The final gas yield is dependent on the carbohydrate, protein and fat content (Weiland, 2010). A simple overview of methane production by anaerobic digestion is given in figure 2.1. The digestion process to obtain biogas can be decomposed into four phases. For every

[1] An anaerobic organism doesn’t require oxygen for growth. By contrast, an aerobe organism needs oxygen to grow.

phase, different groups of microorgansims are responsible for the metabolic transformation. The four phases are:

- *Hydrolysis*: complex organic matters, like proteins, are converted into simple soluble products, such as amino acids;
- *Acidogenesis*: conversion of soluble products to volatile fatty acids and CO_2;
- *Acetogenesis*: tranformation of volatile fatty acids into acetate and H_2;
- *Methanogenesis*: conversion of acetate and CO_2 + H_2 to methane gas.

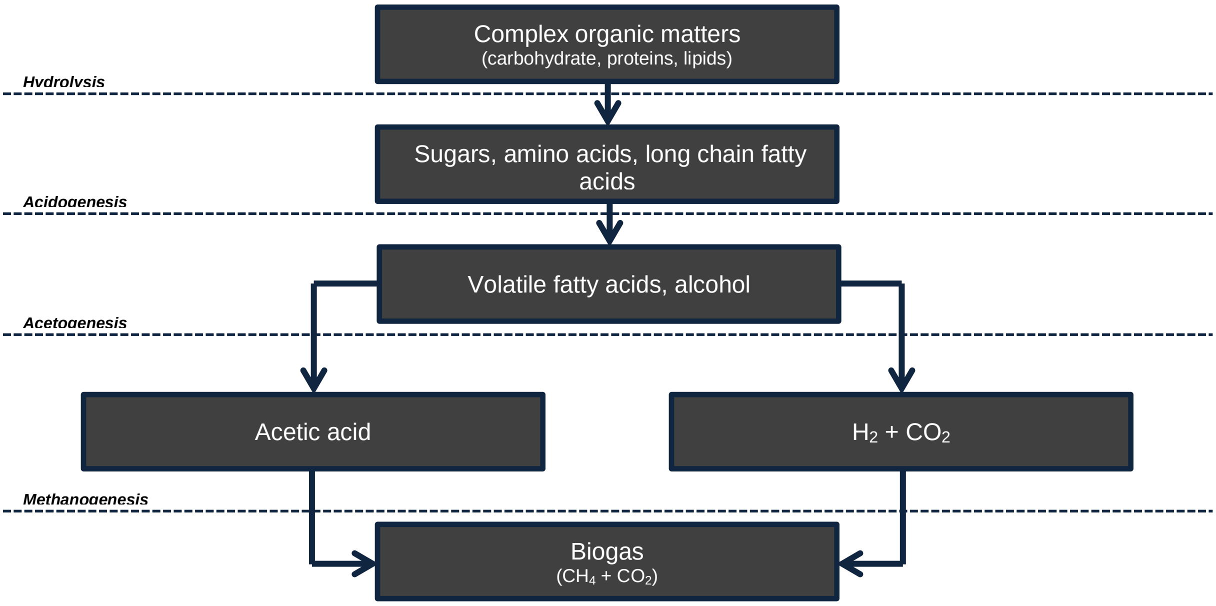


Figure 2.1: Schematic representation of methane production by anaerobic digestion (Based on Reith *et al*., 2003 and Weiland, 2010).

2.2 Basic factors affecting anaerobic digestion

Literature describes environmental factors which strongly influence the digestion process. Basically, there are some primary factors the owner of a biogas plant can use to control the process. These factors are successively: temperature, pH and toxicity. With respect to temperature, a distinction is made in three temperature regimes: psychrophilic (10 – 20 ºC), mesophilic (20 – 40 ºC) or thermophilic (50 – 60 ºC). The lower the temperature, the slower the bacterial growth and conversion processes. Therefore a longer retention time is needed. Weiland (2010) stresses the point to keep temperature constant during the digestion process. Fluctuations in temperature will lead to a lower biogas production. To run the digestion process with a high temperature regime is more challenging as it is difficult to let the temperature stay constant. It asks more monitoring efforts. From the latter perspective, a positive side of psychrophilic digestion is that bacteria are more stable due to the lower temperature. The thermophilic temperature regime is especially used when the waste is discharged at a high temperature or when pathogen removal is a necessary step (Reith *et al.*, 2003). The choice which temperature regime to choose most of the time involves some trade-off decisions as each regime has its own advantages and drawbacks (table 2.1).

Table 2.1: Advantages and drawbacks of different temperature regimes (Source: Mallon and Weersink, 2007).

Temperature	Advantages	Drawbacks
Psychrophilic	Most stable bacteria No additional heat required Least monitoring intensive Least costly to construct Easiest to manage	Longest retention time (not always an issue) Lowest production of biogas Lowest pathogen reduction
Mesophilic	Bacteria more stable than with thermophilic temperature regime Shorter retention time than with psychrophilic temperature regime Moderate monitoring required Moderate management required	Additional heat required Moderate pathogen reduction Costly to construct
Thermophilic	Shortest retention time Highest production of biogas Highest pathogen reduction	Least stable bacteria Additional heat required Most monitoring intensive Most costly to construct Hardest to manage

The pH value is especially important during the last phase, methanogenesis. In this phase, the pH value should be neutral, which means pH values between 6.5 and 7.5. If the pH value is not within this range, it affects the methane production negatively. Finally, the existence of compounds containing toxic effects at excessive concentrations adversely affects methanogenesis (Reith *et al.*, 2003). The anaerobic digestion process is complex. Running a biogas plants successfully, necessarily involves knowledge of the digestion process. This is a prerequisite for the success of biogas production.

2.3 Sources of biogas production

There are several ways how biogas can be obtained. Statistics Netherlands (CBS Statline, 2011) distinguishes four categories (figure 2.2):

- landfill sites;
- wastewater treatment;
- co-digestion of manure;
- other sources.

Figure 2.2 suggests that biogas production out of land fill sites is slightly declining. Using this source, biogas is obtained out of organic matter from a landfill site. A sound reason for the decline could be that organic waste deposed is declining and therewith also the percentage organic matter (Bio-energie cluster Oost-Nederland, 2011). Biogas out of sewage sludge has remained stable over the last five years. The overall growth of biogas production is mainly caused by the third source, biogas production out of co-digestion of manure added with other sources of biomass. This source has shown a spectacular growth over the last six years (see figure 2.2). The remaing part (other sources) has also shown an increase over the last years. In this category, a substantial part is biogas obtained by the processing food industry from waste water. Another rising source in this category is biogas production out of vegetable, fruit and yard (VFY) waste (CBS, 2011).

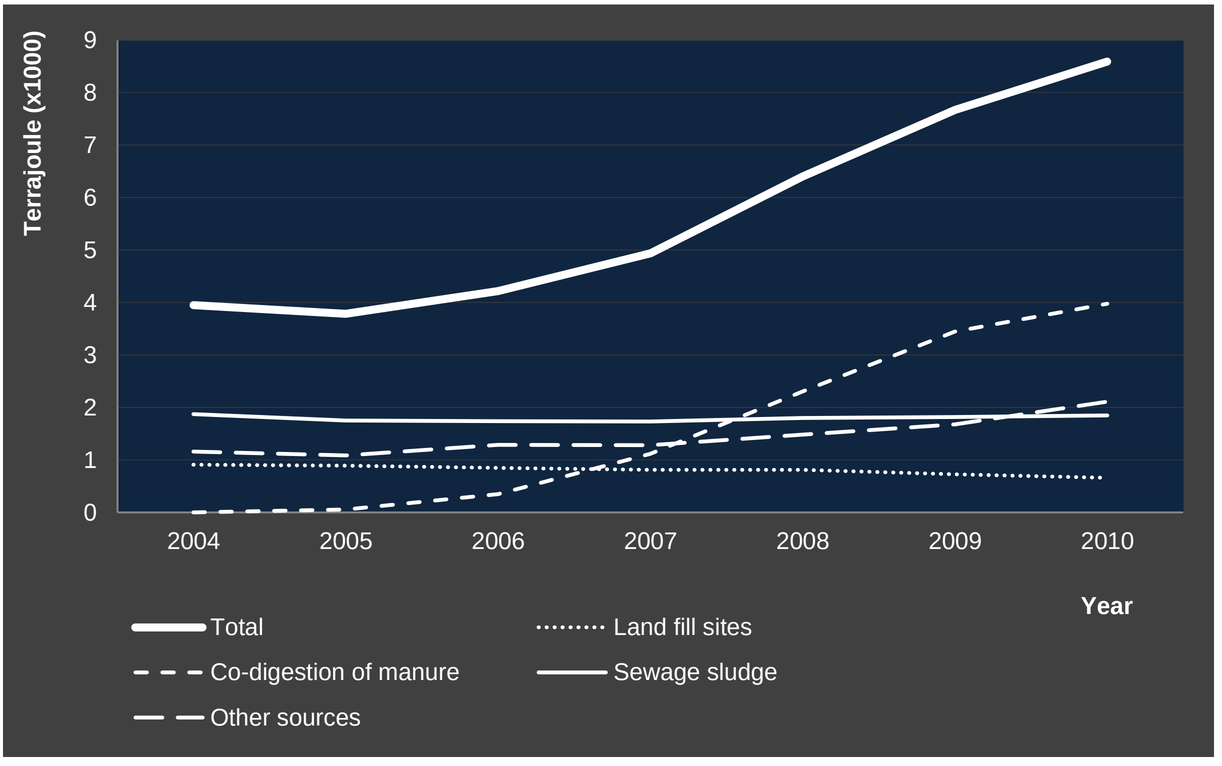


Figure 2.2: Biogas production sources used for renewable energy in The Netherlands (Source: CBS Statline, 2011).

2.4 Digested substrate

As a result of anaerobic digestion of organic materials, besides biogas also digestate is produced. The latter is the substrate which is left after digestion. Digestate is a valuable fertilizer due to its nitrogen content and fertilization effects of its flow properties (Weiland, 2010). Especially when longer retention times and higher temperature regimes are used, anaerobic digestion is also able to inactivate weed seeds, bacteria, viruses and other possible pathogens. Furthermore, anaerobic digestion reduces odour. These properties also apply for digested animal manure when co-digestion techniques are used. In several publications, digestate is presented as being a substitution possibility for ordinary animal manure. Dutch legislation recognizes digestate as a fertilizer when at least 51% of the digested organic materials consists of animal manure (Courage and Innovatienetwerk, 2007). An extra option is to separate and further refine digestate. Doing this, a possibility is shaped to export minerals from areas with excess of manure to areas where shortages appear (Holm-Nielsen *et al.*, 2009).

2.5 Biogas utilization

The production of biogas never is the end-goal. Biogas will always be further converted into usable energy products. Holm-Nielsen *et al.* (2009) distinguish seven utilizations:

- production of heat and/or steam;
- electricity production with combined heat and power production (CHP);
- industrial energy source of heat, steam and/or electricity and cooling;
- upgraded and utilization as vehicle fuel;
- production of chemicals and/or proteins;
- upgrading and injection in the natural gas grids;
- fuel for fuel cells.

Which utilization is best depends on many factors. An important factor is the scale. If there is production on a large scale, like at industry level or municipal level, then also more expensive utilizations are optionable. Examples of large scale operations could be the production of biogas out of sewage sludge, industry waste sludge and waste water. Biogas production at industry level can function as source of heat, steam and/or electricity and cooling. Instead of producing biogas more advanced products as chemicals and/or proteins could be produced out of different sources of organic materials. This is referred to as bio-based economy.

In The Netherlands, the minimum scale is on-farm scale where biogas is obtained out of (co-)digestion of manure. The production of biogas on this scale has received much attention in the literature. Sometimes, farmers set-up a collaboration to scale up biogas production (see for an example Gebrezgabher *et al.*, 2010) or start joint-ventures with energy companies (CBS, 2011). Besides farmers, also contractors start with producing biogas. Most companies use the mesophilic temperature regime and run a CHP to produce electricity (Langeveld *et al.*, 2010). Till August 2006, electricity generation was the only conversion which was subsidized by the Dutch government via the MEP regulation. If a CHP is used for utilization of the biogas, besides electricity generation also heat is produced. Part of the heat is used to heat the production location or used in the production processes on the site. However, the heat is often not fully employed (van der Werf, 2010; Langeveld *et al.*, 2010). The remaining heat could for example be sold to neighbouring households. Problem here is that heat can only be transported over a limited distance (Reith *et al.*, 2003). There are more – possibly with higher financial rewards – utilizations which are technically feasible but not from an economic point of view. Bekkering *et al.* (2010) distinguished four utilizations on-farm: production of electricity, production of heat, production of heat and electricity and upgrading to green gas and injection in the gas grid. Other utilizations were not considered. Their final conclusion is that an overall picture of what a sustainable gas market would look like on an operational level is missing. Another more advanced utilization is upgrading biogas to vehicle fuel. In Sweden a considerable amount of cars now drive on upgraded biogas (Persson *et al.*, 2006). Many developments are necessary to ultimately drive a car which uses upgraded biogas. Cars have to be adapted making them suitable for driving on upgraded biogas. New fuel pumps have to be installed in a certain area. If there is only one fuel pump for upgraded biogas, car drivers cannot make a long trip because they can only refill at that particular pump. In Sweden, the development has been initiated by several factors including tax exemptions, a government investment programme, tax reduction and free parking in several cities (Persson *et al.*, 2006).

2.6 Conclusions of this chapter

Biogas is the result of an anaerobic digestion process which occurs spontaneous, for example in the stomach of a dairy cow. Humans have imitated this process of making biogas which can be utilized in many ways. The main sources are landfills, sewage treatment plants and (co-)digestion of manure at farms or farm related companies.

In The Netherlands, biogas production has increased sharply from 2005 onwards. This likely has to do with a subsidy regulation the Dutch government introduced in 2003. Stimulating the renewable electricity production with the subsidy led especially to (co)-digestion of manure projects. Within these realizations biogas is mainly used to produce electricity. The heat becoming available is most of the time not fully commercialised. Part of the heat is employed for private use. Other utilizations, like upgrading biogas till natural gas or vehicle fuel, are scarcely applied. This can be due to an absent institutional environment which shapes the conditions for these utilizations.

Chapter 3: Stakeholders

In this chapter we answer the following research question: Which stakeholders play a role in the biogas production sector? An economic and institutional analysis requires knowledge on which stakeholders are involved in the production and use of biogas. As we have seen in the first chapter, different sources of biogas production exist. Moreover, biogas is utilized in different ways. However, anaerobic digestion of manure often with co-products, nowadays is the major source for biogas produce (Peene *et al.*, 2011). The utilization of the biogas frequently is done by a CHP-unit generating electricity (and heat). The excess heat often is not utilized (Gebrezgabher *et al*., 2010; Langeveld *et al*., 2010). For these reasons we restrict ourselves to a stakeholder analysis which only takes the aforementioned source and utilization into account. Nevertheless, part of the analysis also counts for other sources and utilizations.

The chapter is divided into the following sections. Section 3.1 describes stakeholders in the public sector of the economy. Section 3.2 describes stakeholders in the private sector. In section 3.3 we discuss the participation of stakeholders in the different phases of a biogas project. In section 3.4 we conclude.

3.1 Public sector

Government. The government as a stakeholder can be split up into three different levels: European Union (EU), national and local. To start with the latter one, at local level the government is of great importance as they grant permits which allow for investing in biogas production at a certain location. These permits have to be granted to ensure rules about land use planning, environment issues in general and specific rules regarding digestate and input regulation (AgentschapNL, 2011a). At national level, the government recognises the need to become less dependent on fossil fuels and in addition to reduce greenhouse gas emissions. Therefore it has set ambitious goals to reduce aforementioned problems: a 30 per cent greenhouse gas emission reduction and a 20 per cent increase in sustainable energy use in 2020. Many countries within the EU, including The Netherlands, have adopted policies to stimulate sources of renewable energy production. Especially feed-in tariffs are used as an incentive measure (Murphy *et al.*, 2011). A feed-in tariff is a policy instrument providing renewable energy producers a long-term contract guaranteeing a fixed payment per unit of output, usually per kWh or Nm^3 of gas. Renewable energy production costs are much higher than the costs to produce energy using fossil fuels. At this moment, often a feed-in tariff is necessary to make a biogas project economically feasible (Gebrezgabher *et al*., 2010). In 2009, the EU has formulated a directive which aims to have 'established a common framework for the production and promotion of energy from renewable sources' (European Union, 2009). In this directive it is pointed out that individual member states have to establish national action plans. In those plans every member state explains how the targets set by the EU in the 2009/28/EC Directive, will be reached. There are two ways to fulfil the targets: (1) total energy consumption will be reduced, (2) less energy from renewable sources will be required (European Union, 2009).

Grid operator. In the Dutch electricity market, the grid operator is a public company. The grid is divided into a high and medium/low voltage grid. For the latter, regional grid operators are responsible. When a biogas plant owner wants to sell his generated electricity to an electricity supplying company, the regional grid operator is responsible for the connection to the grid and transportation of the electricity.

Research institute. In chapter 2 we have seen that biogas production is a complex process. Research institutes play a major role supporting the biogas sector with (fundamental) knowledge. They execute trials with new, unproved technologies. Their research for example can help the biogas sector to make some efficiency improvements. Governments also make use of these research institutes to support their policies with scientific underpinnings. For example, the level of the subsidy payments of the SDE programme is determined by the ECN research institute in The Netherlands (Lensink *et al.*, 2011). Here we positioned the research institute as a stakeholder, but universities or private companies can fulfil the same role.

3.2 Private sector

Bank. The investment cost for a biogas plant is high. Lensink *et al*. (2011) estimate the investment costs for a biogas plant using manure and co-products at € 2740/kW_e. They further assume an average plant size of 2 MW_e. This would imply that the average investment equals € 5.5 million. Normally, such investment costs cannot be paid with own capital. Therefore, the bank is needed to provide a loan.

Biogas plant owner. The central stakeholder is the owner of a biogas plant. The owner can be a farmer who is extending his farm activities with biogas production. There are also agricultural service supply agencies who extend their business producing biogas (Van der Werf, 2010). Other forms of ownership also exist, like a co-operative or an investing company which invests in renewable energy, but these are exceptions.

Constructor. The actual construction of a biogas plant is often done by specialised companies which have the technical knowledge of how to construct such a plant. These constructing companies also often operate internationally, like the construction company Thecogas does. This company has constructed biogas plants in Africa, Asia and Europe (thecogas.nl).

Consultant. Sometimes a consultant also operates as a constructor. But in many cases, external consultancy companies are attracted to give advice about a particular problem. Before the construction phase, subsidy and permit requests can be outsourced to a consultant. At the start-up phase after the biogas plant has been installed, problems like odour nuisance, low methane production or menu composition are submitted to consultants (Van der Werf, 2010).

Digestate customer. After each retention time period, new biomass is fed into the biogas plant and remaining substrate (digestate) has to be disposed. Currently, despite its attractive properties, digestate is disposed against high costs at the manure market. This has to do with the surplus of animal manure present in The Netherlands and the fact that digestate only is recognized as animal manure in relevant legislations. In some cases digestate is used as fertilizer on own land, then the biogas plant owner uses digestate himself. If no own land is available, the digestate is used by arable farmers within or outside the country. Consequently, high disposal costs have to be paid (De Hoop *et al.*, 2011). Sometimes, the digestate is processed to satisfy customer needs, for example by pressing, drying or hygienizing the digestate.

Electricity supply company. The generated electricity is sold to electricity supply companies, like Greenchoice who at this point in time buys electricity from 50 biogas plants in The Netherlands (Greenchoice.nl). The biogas plant owner as well as the electricity buyer need a regional grid operator for the connection to the grid and transport of the electricity.

Input supplier. In this analysis we assume that biogas is produced out of manure and co-products. It could be that – when the farmer is also the owner of a biogas plant – manure is obtained from the own farm just like certain co-products (e.g. maize). But frequently the owner has to buy different co-products and extra manure. Suppliers could be other farmers or the food industry who offer organic waste streams. Additional manure sometimes is necessary for the reason that at least 51 per cent of the digestion menu should consist of manure. Acquiring some extra manure is not a problem under current conditions of the manure market in The Netherlands. Many regions have excess of manure. For example, in the Noord-Brabant province, a pig farmer pays disposal costs of around 20 euro per ton and a dairy farmer situated in the Noord-Holland province 6 to 8 euros per ton (Courage and Innovatienetwerk, 2007).

Neighbourhood. Whoever is living in the neighbourhood of the selected location where the biogas plant is to be constructed can show NIMBY (Not-In-My-Backyard) behaviour, for example concerns about increased transport movements, emission of pollutants, smell and transmission of diseases. A consequence of such behaviour can be that permits will not be granted due to protests. The construction phase then will be delayed or even not reached. Therefore, possible concerns of people living in the neighbourhood of the selected location should be taken into consideration.

Trading agent (potential). Adding co-products to the digestion process of manure increases biogas production substantially. For that reason, trading agents see opportunities to do intermediary trade between input suppliers and biogas plant owners. However, these co-products are scarcely available. The food industry, who can be an important supplier of co-products, indicates that most of the biomass nowadays is efficiently used for food and feed purposes. When the biogas will be used for energy production, it means that the biomass is used for a low quality energy purpose. So, for the food industry using biomass for energy production is a less attractive application (Elbersen *et al*., 2011). Trading agents also are involved in the manure market. Their main role is transporting but sometimes they also buy and then temporary store and blend to get a better homogeneous quality. By having such facilities, they also have the possibility to speculate about prices and fees.

3.3 Stakeholder participation

Each stakeholder provides its own contribution to a biogas plant project, however, that contribution is sometimes restricted to a particular phase. A distinction is made between three phases: developing phase, construction phase and operating phase. In table 3.1 an overview is given of the stakeholders and at which phase(s) they play a role.

For the biogas plant to be a success every stakeholder should be involved in the developing phase. For some of them this is obvious, e.g. the government who grants subsidies and permits and the grid operator who is needed to guarantee a connection to the grid. At first glance, the involvement of input suppliers and (potential) trading agents seems not relevant. However, it turns out that guaranteeing sufficient inputs for the digestion is difficult due to scarcity of good-quality affordable biomass (Elbersen *et al.*, 2011) and its volatile price (Peerlings, 2009). Therefore, starting with securing enough biomass supply in the developing phase can guarantee running the digestion process at the operation phase profitable.

Table 3.1: Overview of stages the biogas owner faces his stakeholders.

	Developing phase	Construction phase	Operating phase
Government	■		
Grid operator	■	■	
Research institute	■		
Bank	■		
Constructor	■	■	■
Consultant	■	■	■
Digestate customer			■
Electricity supply company	■		■
Input supplier	■		■
Neighbourhood	■		
Trading agent	■		■

In the construction phase, less stakeholders play a role as the direct collaboration with part of the stakeholders can be finished, like with the government and grid operator. Still, there may exist contacts with these stakeholders, but there primary contribution has finished. Here the more 'technical-oriented' stakeholders are important for their contribution in constructing the plant. After the plant has been constructed, stakeholders related to transacting inputs and outputs are most important. To the best of the author's knowledge, long-term sales contracts for the produced digestate rarely are used. Digestate often is, just as animal manure, disposed or used on own land. When start-up problems occur, also the constructor and/or consultant are needed to solve these problems.

3.4 Conclusions of this chapter

In this stakeholder analysis we have seen that starting-up a biogas plant cannot be done without involvement of many stakeholders. In the developing phase, nearly every stakeholder seems to be necessary in order to get guarantees about technical and economic issues which play a role at time of construction and/or operation. The conclusion here is that good collaboration with all stakeholders cannot be underestimated.

Chapter 4: Economic and institutional factors

The Dutch government has set goals to reduce greenhouse gas emissions and become less dependent on fossil fuels. Biogas production is recognized as one way to help reaching these goals (Ministerie van Landbouw *et al*., 2007). The potential of biogas utilization is confirmed by many scientists. According to Weiland (2010), it is of increasing interest in order to reduce the greenhouse gas emissions, to facilitate sustainable energy development by replacing fossil fuels.

Despite these recognitions, the Dutch biogas sector faces a lot of barriers preventing it from becoming a viable one. Perhaps this is not so suprising because the sector has been existing for just a couple of years.

In the literature we hardly find work about the economic and institutional challenges biogas production is facing. For the US biogas sector though, over the last couple of years there is a considerable amount of research published about economic and institutional factors affecting the starting of biogas plants (e.g. Altman *et al*., 2007; Altman and Johnson, 2008; Gloy and Dressler, 2010). In most cases, anaerobic digestion (AD) techniques are the topic of discussion. Research mainly used transaction cost economics as a way to explain the limitations of starting a biogas plant. Below we will list several economic and institutional challenges which are important for the Dutch case. Some points of interest are described in the US literature already; however, these issues are expected to be relevant for the Dutch biogas sector too.

In this chapter, the aim is to study economic and institutional factors affecting the viability, keeping technological issues outside the discussion. First we explore the concept of institutions in more detail to clarify how we make use of this concept (section 4.1). Then, different categories of problems are discussed: in section 4.2 we discuss market failures, then in section 4.3 we look to forms of asset specificity which can be problematic, section 4.4 describes some forms of uncertainty present and in section 4.5 we look in more detail to government policy and its implications. Section 4.6 describes other institutional factors and section 4.7 concludes.

4.1 Institutions: definitions

The concept of ‘institutions’ is broadly used in economics, political science and sociology. Scott (1995) has studied this concept and made a useful categorization of ‘three pillars of institutions’: regulative, normative and (cultural) cognitive institutions.

Regulative institutions can be described as ‘regulative processes involving the capacity to establish rules, inspect or review others’ conformity to them, and as necessary, manipulate sanctions – rewards or punishments – in an attempt to influence future behaviour’ (Scott, 1995). Examples are laws, codes of conduct, contracts or technical norms, but regulative institutions also encompass incentive schemes like taxation, subsidies and public procurement policies (Truffer *et al*., 2009). Especially economists use the concept of institutions in this way to describe formal rules.

The next two concepts have to do with informal institutions. Normative institutions can be described as ‘normative rules that introduce a prescriptive, evaluative, and obligatory dimension into social life’ (Scott, 1995). They include values, norms, standards of good practice, work norms and conventions. They are not backed with sanctions but rather set what is right and what is wrong (Truffer *et al*., 2009). Cognitive institutions can be described as ‘rules that constitute the nature of reality and the frames through which meaning is made’ (Scott, 1995). They include visions, expectations, broadly shared role models, perceptions.

4.2 Market failures

Without intervention, using the price mechanism, the market will bring supply and demand of goods or services together. A perfect free-market situation is rather exception than rule; frequently different kinds of market failures exist. Different forms of market failures will be discussed next: the public good characteristics and positieve externalities of biogas production (section 4.2.1), the information asymmetry which can exist between economic actors in the biogas supply chain (section 4.2.2) and the notion of bounded rationality of actors (section 4.2.3).

4.2.1 Public good characteristics and externalities

Biogas production has some aspects which are of public interest. In other words anaerobic digestion of manure and possible co-products added produces positive externalities that contribute to the production of several public goods (e.g. odour control, reduction in pathogens and reduction in greenhouse gas emissions). For these public good characteristics the biogas plant owner doesn’t get paid for. One can doubt the relevance of the contribution to public goods as the owners of biogas plants often are also the polluters.

Nevertheless, biogas production has positive externalities, i.e. non-marketable outputs which are not priced (Yiridoe et al., 2009).

4.2.2 Information assymetry

If there is an information assymetry present (also called assymetric information) between two players, the information is available but one player knows more than the other. In a contractual relationship, information assymetry implies that one economic actor knows something the other actor does not (Slangen *et al*., 2009). This phenomenon can also be present in the biogas supply chain. An example of such an information asymmetry could occur in the market of co-products originating from the food industry. In the previous chapter we have seen that these waste products most of the time are already efficiently processed for feed and food purposes. According to Elbersen *et al.* (2010), the expectation is that some waste streams will fall vacant and become available for biogas production especially when policy obstacles are solved. Information about the state of those waste streams is only known to the food industry itself. This leads to an information assymetry between the interested biogas plant owner and the food industry. A trading agent here possibly could bring a solution if he is be able to gather this information and transfer it to demanders, like the biogas plant owner.

4.2.3 Bounded rationality

The assumption of fully rational-behaving actors in neo-classical economic theory is critized. More realistic is the notion of bounded rationality. According to Slangen *et al.* (2009): 'People have only limited possibilities and abilities to obtain and process information, and the capacity of human beings to formulate and solve complex problems is limited.' Looking to the biogas case, much information is needed concerning regulation (permits and subsidies), performance of the biogas plant etc. To deal with bounded rationality information can be obtained from third parties (e.g. consultants) but this goes with a cost.

Reise *et al.* (2010) have studied the decision-making behaviour of German farmers investing in bioenergy. They have found that those farmers had heterogenous investment tresholds. The decision to invest is mainly driven by the cost of capital and the individual risk attitude. Other decision variables, sustainability and non-monetary objectives, play a minor role. The results show that bounded rationality has an effect on the behaviour of real decision makers, their behaviour was not in line with the outcomes of normative forecast models.

4.3 Asset specificity

Biogas plant investments have a high asset specificity (transaction-specific assets). This means that the investment has a lower value when it is employed for other purposes, due to its specificity for biogas production. To make this more specific, we can make a distinction in four types of asset specificities (Hendrikse, 2003). Spatial asset specificity or site specificity is about ex-ante decisions to minimize inventory and transportation costs, in other words: the location creates dependency (Altman and Johnson, 2008). Then, human asset specificity: special human skills are needed for the work. It is a learning by doing exercise. Thirdly, dedicated asset specificity means that the investment is made on the prospect of selling the highly dedicated output to a specific customer. The investment is done on the basis of the specific transaction-relationship. If this customer breaks up the agreement, the investor is stuck with the output. Physical asset specificity refers to assets which are designed for making a specific product. It has a narrowly defined use (Slangen *et al*., 2009). The last type is time or temportal asset specificity: timing of the asset's use is specific and critical (Altman and Johnson, 2008).

For the Dutch biogas sector the presence of asset specificity is obvious. The location where the biogas plant is build matters in order to minimize transport and inventory costs (section 4.3.1). Special human skills are needed to know how to produce high methane yields (section 4.3.2). Other types of asset specificity seem not inevitably to be present (section 4.3.3).

4.3.1 Spatial asset specificity

As the location for a biogas plant is important, spatial asset specificity is likely to be high. According to Meijer *et al*. (2008) the investment cost for a biogas plant with a combined heat-power unit (CHP) differs among regions; in the northern and eastern part are the investment costs lower than in the southern part of the Netherlands. This has to do with disposal costs of the digestate. In northern regions there is land available for manure spreading while in the southern regions (mainly intensive livestock farming) disposal costs have to paid to get rid off the digestate as no land is available to spread. Transportation is costly due to the high weight of these products (Peerlings, 2009). Gebrezgabher *et al.* (2010) state that 'feedstock and digestate transport have a significant effect on the economy of the system'. The location should be chosen in such a way that transport and inventory costs are minimized. A favourable location neighbours the input suppliers as well as the customers of the end-products, like it is the case with an agro-park (Ge *et al*., 2011).

4.3.2 Human asset specificty

Furthermore, human asset specificity is present. Skills, knowledge and experience are specific to the production process of biogas. Running a biogas plant efficiently involves knowledge of technical conditions, like knowing which inputs can be put together resulting in a good digestion menu and which temperature is desirable. The digestion process needs a professional operator who has an understanding of methane production. Owners of a biogas plant do not always have this knowledge. A solution would be to hire a professional which is responsible for the digestion process to control and optimize the process (Courage and InnovatieNetwerk, 2007).

4.3.3 Other types of asset specificity

Thirdly, dedicated asset specificity is not inevitably present. It depends on which utilization techniques are chosen. At this moment, most biogas plants use a CHP for utilizing the biogas to generate electricity (and heat). Electricity can be sold to many customers, the one who is willing to pay the highest price per kWh receives the generated electricity (personal communication with a plant manager). The remaining output, the digestate, usually is not further processed and therefore disposed as animal manure to other areas or spread on own land. An example of dedicated asset specificity can be found in the study of Gebrezgabher *et al.* (2010). In this paper, a biogas plant is studied which has adopted advanced techniques for further processing the digestate, including a seperation of the digestate into a solid and a liquid fraction. The idea was to sell the liquid fraction as a substitute for artificial fertilizer in stead of paying disposal costs to get rid off it. However, regulation didn't allow for this utilization and the owner of the biogas plant still had to pay high disposal costs to get rid off the processed digestate (personal communication with a plant manager).

In fact, one can look at the presence of physical asset specificity in two ways: either with respect to the facility itself or to the digestion process. For the latter aspect, physical asset specificity is not inevitably present as the digestion process can be executed with all kinds of biomass. On the other hand, to obtain high biogas production rates, the composition (quality, quantity and type of the ingredients) of the digestion menu matters. Consequently, this is a trade-off. For the biogas facility as a whole, we can say that physical asset specificity is present. The facility itself has a narrowly defined use: it can only be used to perform anaerobic digestion of biomass.

The final is the temporal asset specificity. It is considered that this type of asset specificity is not present. Although biogas processing contains a timing aspect, we see this as part of the human asset specificity wherein a professional operator should know about the timing aspects of the digestion process.

4.4 Uncertainty

To analyse the role of uncertainty, first a distinction can be made between behavioural uncertainty and environmental uncertainty (Bijman, 2002). The latter refers to changes in the environment of the transaction leading to disturbances in transactions. Examples of such disturbances are the complexity and dynamism of markets, policies and technologies. Behavioural uncertainty has to do with the behaviour of the transaction partners (linkages with opportunistic behaviour).

In this section the focus will be on environmental uncertainty. Two types of such uncertainties will be discussed: markets and technologies. Uncertainty about policy is covered in section 4.5.

Producing biogas necessarily involves being active at a couple of markets for example to secure enough inputs for the digestion process. Agricultural markets in general are characterized by low price elasticities of demand and supply (Peerlings, 2009). A consequence is that small fluctuations in harvest yield or demand cause a big price effect leading to instable prices. These large price shocks in agricultural markets can also cause an effect on other markets where products are marketed which are related to those agricultural products. An illustration of this are the markets of barley and brewers' spent grain. The link between these two markets is the production of beer. Barley is used as an input to produce beer. One waste product of the production process of beer is brewer's spent grain which is an excellent co-product for digestion because of its high fat and protein content (Elbersen *et al*., 2011). When at a particular moment the yield of barley is lower than expected, prices will sharply increase and so the price for brewer's spent grain too. Besides the beer producer it affects others, like the biogas producer who now has to pay more in order to secure enough co-products for a stable digest menu. The final biogas yield is dependent on a good digest menu. Thus, instable prices create uncertainty for biogas producers because they affect the production costs and revenues, and therefore profitability. According to a benchmark comparison of 30 biogas plants using mostly co-digestion of manure techniques, the costs for raw materials have been increased from 7,3 cents per kWh in 2009 to 7,8 cents per kWh in 2010. The average total amount of electricity produced was 7.300.000 kWh. (Rabobank, 2011). This would imply an average increase in raw material costs of 36.500 euro. This challenge of rising input costs forms for some actors an argument to apply for anaerobic digestion of manure without co-products, so-called mono-digestion (LTO Nederland, 2011; Natuur & Milieu, 2011).

Another environmental uncertainty is about technologies. For both, anaerobic digestion of biomass technologies and biogas utilization technologies, different options exist. With respect to the anaerobic digestion plants itself, different types of plants are offered by numerous constructors. For the investor it is a complex decision problem which type to choose, also taking in mind that anaerobic digestion techniques still develop further. Besides, as earlier mentioned, there is also the option of the mono-digestion technique. According to the aforementioned benchmark comparison between digesters running on manure and co-products, the most economically successful biogas plants work with sober, reliable and proven techniques and a plant containing enough digestion capacity (Rabobank, 2011). With respect to biogas utilization techniques, uncertainty is even higher. The investor is largely dependent on actors who are setting the technological and institutional conditions. Here the government plays a major role as it can facilitate new utilizations with policies allowing for a particular technique or stimulating another. A biogas plant has to co-operate with grid operators, electricity and gas supplying companies, in order to make a specific utilization possible. Currently, upgrading biogas to make it suitable for injection into the gas grid is promoted, e.g. through a subsidy programme. To make this type of utilization possible, gas hubs will be established (AgentschapNL, 2011b). However, two years ago the most important utilization concept used was a CHP to generate electricity (and heat) and that is the reason why most of the current plants utilize biogas in this way.

4.5 Government policy

The government at EU and national level are decisive as their actions can make biogas production and use successful or not. Especially when market failures exist, as described earlier in this chapter, government intervention can be justified (Slangen *et al*., 2009).

Different types of policy instruments are available for a government (see Oskam *et al.*, 1998). The EU initially shapes the conditions for individual decision making. Conditions are outlined in EU directives, like the 2009/28/EC Directive (European Union, 2009) in which the necessity of renewable energy sources is stated and goals are set to reach a certain percentage share of renewable energy share in total energy used. In the aforementioned directive, individual EU members are obliged to develop an action plan which should describe how the set goals are reached and which policy instruments at national level will be used.

The national government can provide subsidies, give tax exemptions and provide other economic incentives to catalyse market development. In the Netherlands, biogas plants are dependent on government subsidies as the national government recognises biogas production as a tool to reduce greenhouse gas emissions and a way to become less dependent on fossil fuels (Ministerie van LNV *et al.*, 2007). The consequences of subsidizing, market distortions and social welfare losses, can be seen as a cost for reducing greenhouse gas emissions and using less fossil fuels (Peerlings, 2009).

Government interventions are key determinants for the success of biogas production and use. Advanced utilizations for biogas cannot be applied when there is no well-developed institutional environment. For example, when upgrading biogas to vehicle fuel, like in Sweden where a considerable amount of cars now drive on upgraded biogas, many developments are necessary to make such a utilization possible. The government has policy instruments to make car driving on upgraded biogas possible as well as attractive. Without government intervention, these kind of utilizations have less chance to develop. Cars have to be adapted for driving on upgraded biogas, new fuel pumps have to be installed to establish a network of fuel pumps guaranteeing a sufficient cruising range. In Sweden, this type of biogas utilization has been supported by several policy instruments including tax exemptions, a government investment programme, tax reduction and free parking in several cities (Persson *et al.*, 2006).

Also for the Netherlands, without a co-operating government the institutional environment can prevent the biogas sector to become viable. This major influence of the government can also cause major challenges. Two challenges are described below: time-inconsistency (section 4.5.1) and the non-existence of a level playing field (section 4.5.2).

4.5.1 Time-inconsistency

Despite the national government efforts to subsidize renewable energy production, there is much uncertainty about the continuity of subsidies. In 2003, the Dutch national government introduced the MEP[2] regulation to subsidize renewable electricity production projects for 10 years. But on the 18th of August 2006 the MEP was cancelled. Only approved projects before closing date got the subsidy payments for the full period promised. In January 2008 a new subsidy programme was introduced: the SDE[3] programme. The new subsidy programme compensates the cost difference between sustainable and conventional energy production since it is more costly to produce renewable energy. Nowadays (2012) there is the SDE+ programme which is slightly adapted with respect to cost effectiveness issues (Agentschap NL, 2010).

To some extent the switch to new subsidy programmes can be seen as a special form of opportunistic behaviour on the part of the government, called time-inconsistency. Gloy and Dressler (2010) refer to this as ‘uncertainty over public policy’. At a certain point in time policy

[2] A kWh subsidy called ‘Environmental quality of electricity production’
[3] Stimulation of renewable energy production

makers consider a policy to be optimal, but after a period, it is no longer seen as optimal and a new policy comes up. The consequence is that interested people form their expectations and anticipate a change in policy. In the end, the goal of the policy maker is not met (Slangen *et al*., 2008). For the biogas production case, it could e.g. happen that actors that are interested in setting-up a biogas plant, are reluctant to take the investment decision due to the time-inconsistency. At the end of 2006, 64 digestors were established and for the next year 400 small-scale combined heat and power projects had been planned. Due to the changes in the subsidy programmes, a large number of the planned investments were either aborted or put on hold (Langeveld *et al*., 2010).

4.5.2 Level playing field

Several feasibility studies (Courage and InnovatieNetwerk, 2007; Meijer *et al*., 2008; Wilt and Boosten, 2011) have indicated the non-existence of a level playing field with neighbouring countries, particularly Belgium and Germany, due to differences in regulation. In the Netherlands, a smaller amount of products are allowed for co-digestion compared to neighbouring countries. In other words the so-called ‘white list’ is unequal. Starting point for allowing the use of a co-product for digestion is the assessment if that particular biomass stream conforms to the definition of biomass as notated in the EU 2001/80/EG Directive (Courage and InnovatieNetwerk, 2007). If not, it could be the case that valuable co-products originating from the Netherlands are transported to digesters in other countries having less strict rules. If we speak about a market of co-products, then there is a market distortion present due to the differences in regulation. Also differences in subsidy levels (among countries or periods) could be seen as a form of market distortions since participants who receive the highest subsidy can afford to pay more for inputs.

4.6 Other institutional factors

In this section we describe two missing informal institutions. In the current biogas sector, we observe a missing common vision and a public debate about accepting biogas production.

A common vision how the biogas production sector should look is missing. Different opinions exist about what the optimal digestion technique is. Nowadays there is increasing attention for mono-digestion of manure. Not only digestion techniques are discussed, also utilization techniques. Upgrading biogas to natural gas or vehicle fuel are sometimes seen as better options which generate higher quality energy forms. These diverging visions negatively influence the evolvement of trust and commitment between parties in the supply chain.

Numerous actors have their objections against biogas production and more broadly against renewable energy sources. In Germany, the largest biogas producing country, for example there is commotion about the use of crops for biogas production; 25 per cent of the produced maize (650.000 hectares) is designated to produce biogas and another 15.000 hectares is used to cultivate sugar beets for biogas produce (Boerderij, 2011a). This discussion fits within the classical "food vs. fuel" debate. The discussion point here is how the biomass should be used. When soils are used to produce maize for the production of biogas, soils cannot be used for producing food.

NGOs have their own visions about which renewable energy sources are acceptable. The Dutch NGO Stichting Natuur & Milieu for example, doesn't favour co-digestion of manure; they propose mono-digestion of manure and a focus towards methane emission reduction instead of the primary goal to produce renewable energy (Natuur & Milieu, 2011).

4.7 Conclusions of this chapter

In this chapter we have seen that no stakeholder can be excluded if biogas production and utilization have to become more succesfull and viable. Moroever, the owner of a biogas plant has to take all different asset specificities into account when making the investment decision, for example realizing that a good anaerobic digestion process involves specific skills, knowlegde and experience.

Uncertainty is high in the biogas supply chain. For example if co-products are necessary for the production process, market uncertainties have to be taken into account. Furthermore, technological uncertainty makes it difficult to choose a specific anaerobic digestion and utilization technique.

In addition, the government, especially at EU and national level, is responsible for shaping the right conditions. This is a challenging task, given the described problems of time-inconstistency and an absent level playing field. Furthermore, the existence of several market failures possibly also justifies government intervention.

To develop a vision what a biogas supply chain should look like is the responsibility of many actors. A more common vision would help to build up trust and commitment between different parties in the supply chain.

Chapter 5: Governance structures

The concept of governance structures can be found in the theory of transaction cost economics (TCE). It can be described as the set of public and private rules that govern an economic transaction (Bijman, 2005). Central unit of analysis here is the transaction itself. TCE can be seen as a product of two recent and complementary terrains of economic research: New Institutional Economics and the New Economics of Organisation (Slangen *et al*., 2008). In standard economics, a firm or parts of it are only seen as a production function. Then, the objective is to maximize profits by setting marginal profits to zero given the production function. From this assumption it follows that the market itself is the only goverance structure used. However, the firm itself could be a way to govern transactions as an alternative for the market. This is related to the question of Coase in 1937: why do firms exist? Besides, transactions sometimes are governed via e.g. contracts or done in a co-operative setting.

Using TCE, the characteristics of the unit of analysis, transactions, are studied in order to determine the best-suited governance structure. In the literature, several synonym of the concept ‘governance structure’ circulate. Ménard (2004) often uses the term ‘mode of governance'. Another frequently used term is ‘institutional arrangement’. In this report, we use the term ‘governance structure’.

In this chapter the aim is to determine the most appropriate governance structure for the biogas supply chain. In the next sections, we first distinquish three kind of governance structures (section 5.1) and then analyze the transaction characteristics (section 5.2). In section 5.3 we bundle all findings to determine the best governance structure. Section 5.4 concludes.

5.1 A continuum of governance structures

Initially, within TCE the research was about the market as a governance structure confronted with the alternative of a hierarchy. Later on, it was recognized that a continuum of governance structures, multiple forms of hybrids, exist combining characteristics of both extremes, market and hierarchy. Examples of these are: subcontracting, network of firms, supply-chain system, distribution channels, franchising, collective trademark, partnership, cooperatives and alliances (Ménard, 2004).

Given these different governance structures, we can expect different, sometimes specific, motivation and coordination procedures each with its own advantages and disadvantages. Coordination here refers to the alignment of the (interdependent) activities of two or more parties involved in the same transaction, motivation can be described either as providing proper incentives as well as safeguarding against exchange hazards (Bijman, 2005). If minimizing transaction costs is the goal, that particular governance structure resulting in the lowest transaction costs is chosen. Usually, a continuum of governance structures are possible: market, hybrid or hierarchy (figure 5.1).

Figure 5.1: a continuum of governance structures.

Market. The most generally accepted type of governance structure is the market. Ménard (1995) provided a definition: 'a market is a specific institutional arrangement consisting of rules and conventions that make possible a large number of voluntary transfers of property rights on a regular basis, these reversible transfers being implemented and enforced through a specific mechanism of coordination and motivation, the competitive price system'.

Hierarchy. If a hierarchy is used to govern transactions, all transactions are vertically coordinated in one organisation. Ménard (1995) defines hierarchy as: 'an organisation is an institutional arrangement designed to make possible the conscious and deliberate coordination of activities within identifiable boundaries, in which members associate on a regular basis through a set of explicit or implicit agreements, commit themselves to collective action for the purpose of creating and allocating resources and capabilities by a combination of command and cooperation'. Here the term organisation is the same as hierarchy.

Hybrid. The word itself explains already what is meant with it: a hybrid is a combination of above mentioned extremes. Ménard (1995) inexplicetly gives a definition of a hybrid in this context: 'hybrid forms are characterized by specific combinations of market incentives and modalities of coordination involving some forms of hierarchical relationship'.

5.2 Transaction characteristics analysis

Following TCE theory, five characteristics of observed transactions in a particular setting can be studied in order to determine which governance structure fits best. These characteristics are split-up into two groups of characteristics: human characteristics of the decision-makers (5.2.1) and transaction attributes (5.2.2).

5.2.1 Human characteristics

With respect to human behaviour, TCE builds upon two related assumptions: bounded rationality and opportunistic behaviour.

The first assumption has to do with the fact that a decision-maker never has the ability to capture and process all information to make an optimal decision, for example a decision to invest or not. The human mental abilities are limited. Bounded rationality has a practical significance in a complex and uncertain environment (Slangen *et al*., 2008).

The assumption of opportunistic behaviour means that human actors can behave strategic for self-interested reasons. Forms of opportunistic behaviour could be actors providing asymmetric or distorted information, making promises which are not kept, known as hidden information and hidden action problems. Common in both is the problem of unobservability leading to unequally distributed information among both partners. Hidden information is the case when one party is better informed about the characteristics of the transaction than the other party before the transaction is made, and therefore is an ex-ante problem. A hidden action problem is an ex-post problem. After the transaction has been agreed upon, one party can undertake actions which negatively influence the value of the transaction for the other party. As these kind of opportunistic behavioural problems have been recognized and understood, several solutions have been proposed. Hidden information problems possibly can be tackled with screening, self-selection or signalling. Solution to hidden action problems could be monitoring, incentive contracts, bonding or in-house production (see Slangen *et al*., 2008).

5.2.2 Transaction attributes

Following TCE, three attributes of the transaction can be studied in order to determine the most suiting governance structure: asset specificity, uncertainty and frequency of the transaction. The asset specificity plays a prominent role in TCE, while frequency and uncertainty of transaction play a co-determining role (Bijman, 2002).

According to Hendrikse (2003) asset specificity occurs when the investment has a higher value inside the specific relationship than in an alternative use. Part of the investment cannot be recovered elswhere for an alternative use. That part is sunk into the relationship (sunk costs). Ultimately, this can lead to hold-up and lock-in problems. A distinction can be made as hold-up is more an ex-ante problem and lock-in ex-post (Slangen *et al*., 2008). In case of a hold-up the party which has to make the relation-specific investment worries about being harmed after acceptance of the deal. In other words, there are concerns about giving bargaining power away to the non-investing party. In the end, it results in a hold-up problem: no investment at all. A lock-in problem appears after an investment decision is made. Now the party which is accountable for the relation-specific investment is locked into the relationship and profits can be secured by the non-investing party as the investing party has no other alternatives since the asset specificity is high. In other words, the other party now has the bargaining power to change the agreement to his advantage. A high asset specificity would apply for a more specified governance structure as governance costs (also transaction costs) are higher in order to safeguard against forms of opportunistic behaviour, like the lock-in problem. This is illustrated in figure 5.2: a higher asset specificity increases goverance costs. When governance costs become higher, other governance structures than the market would be preferable as they use different coordination and motivation attributes than the competitive price mechanism of the market. Hybrid and hierarchy governance structures allign transactions in a more administrative way ensuring particular outcomes, like contracting does. Extra costs related to contracting, negotiating, writing and enforcing the contract, then outweigh the cost of being harmed through opportunistic behaviour. In this manner, total transaction costs are minimized.

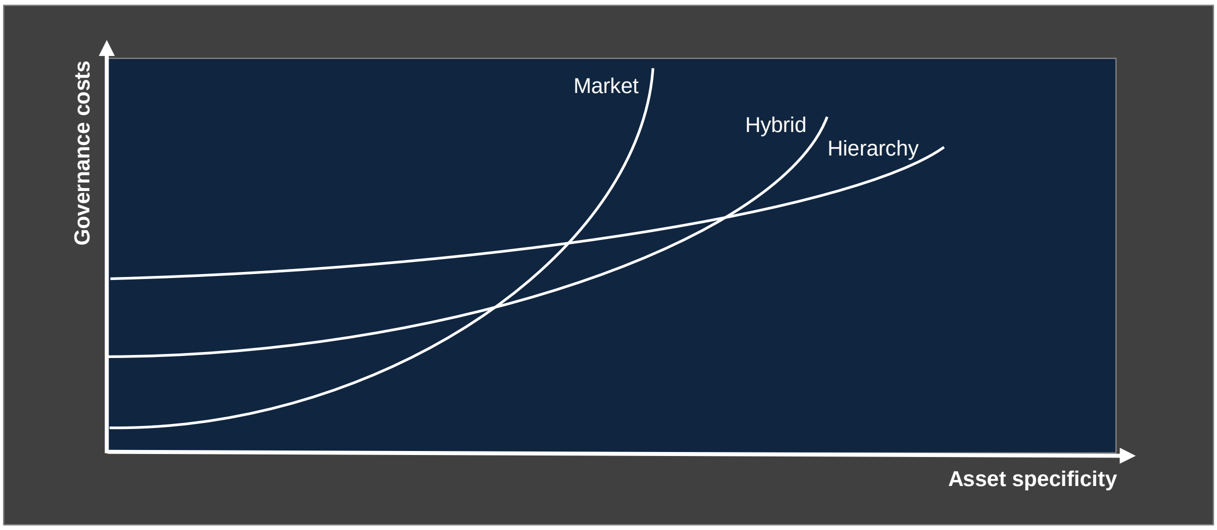


Figure 5.2: Degree of asset specificity and related governance costs determine which governance structure suits best (Source: based on Hendrikse, 2003).

The degree of uncertainty is another attribute of importance. Uncertainty implies that certain outcomes or decisions are unknown and therefore has its influence on coordination and motivation issues and finally transaction costs. In TCE terms: the degree of uncertainty says something about the incompleteness of contracts and the possibilities for ex-post renegotiation (Hendrikse, 2003). This means that hidden information and hidden action appearances cannot be fully excluded. Here, uncertainty is linked with contracting as a hybrid governance structure. This is not suprising because higher degrees of uncertainty give rise to adopt a more specified governance structure, because specific outcomes are hard to determine and hard to prove. On the continuum of governance structures (figure 5.1), this is a move to the right. Using a contract for example, agreements can be set which give more 'certainty' about outcomes.

With the last attribute, frequency, the transaction intensity is studied. A transaction can be a one single event or can be done repeatedly. Especially when the asset specificity is high and therefore a more specified governance structure is preferred, the frequency becomes important. When frequency is high, the costs related to a higher specified governance structure can be recovered more easily (Bijman, 2002). With a low frequency, the costs per transaction is relatively high compared to a situation in which transactions are frequently done and scale advantages can be reached, resulting in lower transaction costs.

Looking at biogas production, sufficient manure and co-products supplies have to be guaranteed. Assuming a retention time of 30 days consequently 12 times a year the anaerobic digestion process is refreshed. To say something about the frequency of these related transactions, the question is whether the biogas plant owner stores inputs in order to buy larger amount of inputs in one time to gain scale advantages. If the biogas plant is not part of a farm with livestock activities, it is expected that manure and some co-products which spoil rapidly are attracted from external sources, delivered at refreshing time to guarantee good quality. For other co-products which spoil less easily, it could well be that these are stored for some time. Prudent to conclude, we may say the frequency of these transactions has a repeated character with a low intensity.

5.3 Most appropriate governance structure

In the previous sections of this chapter, all transaction characteristics have been studied. Only for the last attribute, frequency, we have elaborated on the biogas case. For all other parts, the human characteristics and the remaing transaction attributes, the asset specificity and undertainty, elaborations and findings are presented in chapter 4 about economic and institutional factors.

Bundling these findings wil help us determining the most appropriate type of governance structure. In table 5.1, an overview is given of all findings related to the transaction characteristics studied. The presence of each transaction characteristic has been indicated with a score: one, two or three plusses. Some assumptions have been made for the frequency attribute. It is not sure whether they correspond with reality. It could well be that the frequency characteristics vary largely among biogas producers.

Table 5.1: The transaction characteristics of the biogas supply chain.

	Human characteristics		Transaction attributes		
Transaction characteristic	**Bounded rationality**	**Opportunistic behaviour**	**Asset specificity**	**Uncertainty**	**Frequency**
Presence	+ + +	+ + +	+ + +	+ + +	+ + +
through:	Complex environment: - laws - directives - permits - subidies - own performances	Information assymetries Time-inconsistency government	Site specificity Human asset specificity Dedicated asset specificity	Market Technologies Policies	Repeated character with a low intensity

Among all characteristics, findings indicate that uncertainty has received the highest score. Time-inconsistency due to changing government policies forms a large part uncertainty.

Taking all these notions into account: the high uncertainties present, the different types of transaction-specific assets coupled with the complex environment for decision-making and forms of opportunistic behaviour, a hybrid governance structure fits best. The asset specificity is substantial but not specific enough to justify a hierarchical governance structure and the frequency of transactions is rather low (Ménard, 1995). The high uncertain environment gives rise to adopt a more specified governance structure to get grip on certain outcomes. For example, sufficient supply of co-products could be guaranteed by contracting suppliers and an adequate functioning of the chosen anaerobic digestion technique to produce biogas possibly could be guaranteed by contracting a specialist from the constructing company, to be sure that high methane yields will be reached.

5.4 Conclusions of this chapter

In this chapter, we have used a TCE approach to analyse the biogas supply chain on different transaction characteristics, separated in human characteristics of the decision-maker and the characteristics of the environment. The aim was to compare characteristics of the Dutch biogas supply chain with different governance structures as described in TCE theory. Findings of the previous chapter about the economic and institutional challenges have been used for this comparison.

It turned out that a hybrid governance structure is most appropriate. This has to do with the different asset specificities of biogas production and the high environmental and behavioural uncertainties accompanied with the complex decision-making environment and the possibility of opportunistic behaviour.

However, some forms of uncertainty, like the uncertainty over policies, may better be seen as a risk someone takes. As an individual decision-maker, no transaction costs can be made for safeguarding against this behaviour.

Chapter 6: Case study Biogreen

The central case study object in this chapter is the Green power biogas plant, formerly owned by the Biogreen cooperative, located in the Salland region in the province Overijssel. This particular biogas plant has been the (or one of the) research object(s) of more publications (Gebrezgabher *et al.*, 2010; Van der Werf, 2010; Velthof, 2011). An overview of each contribution of these publications is provided in table 6.1.

Table 6.1: Contribution and outcomes of publications related to the case study object.

Author(s)	Contribution	Outcomes
Gebrezgabher *et al.* (2010)	LP-model of Green power to analyse the economic performance based on NPV and IRR concepts.	Concludes that without subsidizing, economic feasibility is limited. High investment and operating costs, uncertainty about regulations and current low values of digestate and heat are the main causes.
Van der Werf (2010)	Telephone enquiry with 7 biogas plant managers in two provinces Overijssel en Gelderland. With two of them an interview is hold.	Cooperation with local and regional governments is positively judged. Waiting time for granting permits is a nuisance. Heat often is not used. There are no collective-organized digesters (in history, Biogreen was).
Velthof (2011)	Mineral content (liquid fraction) is analysed for its agricultural, economic and environmental effects to study the possibility to substitute it for artificial fertilizers.	Nitrogen and potassium values approach the values of CAN (most widely used artificial fertilizer). Phosphate content is low. Blocking factor for a practical use of the mineral content are the EU regulations with respect to animal manure and artificial fertilizers.

What brings these publications together is the information they provide about the biogas plant Biogreen. The reason why this specific biogas plant has been often subject of analysis is its pioneering role regarding processing of manure (digestate). Biogas production and digestate processing is combined in this plant. Therefore, this case study object cannot be seen as representative of the current biogas sector in The Netherlands.

In this chapter first in section 6.1 we provide some background information about Biogreen. Then in section 6.2 we provide a summary of an interview with the chairman of the Biogreen cooperative. Section 6.3 contains an analysis in which the presence of economic and institutional factors (of chapter 4) is studied for this particular biogas plant. In section 6.4 we conclude.

6.1 General info cooperative Biogreen

In 2002, cooperative Biogreen, a collaboration of 50 swine farmers started a venture with the common goal to lower excess manure supply. In 2007, the Green power biogas plant was established. It is in comparison with other biogas plants a large plant with an installation capacity of 70.000 tons of input per year. Total amount invested was 6,5 million euros (Gebrezgabher *et al.*, 2010).

The main input to produce biogas is pig manure, other products are added to get a better digestion menu resulting in higher methane yields. Anaerobic digestion produces biogas and digestate. Obtained biogas is utilized in a CHP to produce electricity and heat. Generated electricity is sold to a electricity supplying company. What distincts the Green power biogas plant from many others is the extensive digestate processing resulting into two fractions: a solid fraction with high phosphate contents and a liquid fraction. The liquid fraction is further processed into water so that it can be disposed via the sewage system, and into a part which is used in the digester, guaranteeing sufficient dilution of the subsequent digestion menu and into a part which can function as a substitute for artificial fertilizer containing substantial nitrogen and potassium values (Gebrezgabher *et al.*, 2010). Besides the electricity sold, processed digestate finally gives two valuable products: the solid fraction rich in phosphate and the liquid fraction rich in nitrogen and potassium.

Van der werf (2010) indicates that cooperative Biogreen is taken-over by another firm. In October 2009, Bieleveld Bioenergy BV invested 600.000 euros and took a share of 80% in the plant. At that time, several parties advised the members of the cooperative to make use of a professional management to optimize business operations of the plant. However the new investor did not succeed to improve the economic performance (see Appendix I). Almost one year later, in August 2010, Bieleveld Bioenergy BV has become the full owner of the plant. In between, the biogas plant was declared bankrupt after a trade creditor asked for bankruptcy. At time of bankruptcy, total amount of money lend was almost 7 million euros (Claassen, 2010).

These developments gave rise to arrange an interview session with the former chairman of the cooperative to find out the reasons for the take-over.

6.2 Interview summary

High disposal costs of manure gave rise to search for a solution to lower excess manure supply. Starting up a biogas plant would be attractive either to digest manure in order to get electricity and heat and to process the digestate into valuable products that could be exported to get rid of the excess manure. The investors got an innovation subsidy for the investment and a MEP-subsidy for the generated electricity. However, at time of construction the MEP subsidy programme was cancelled because of its high expenditures. A more cost effective subsidy programme (SDE) was announced. In the end, the investors got a transitional arrangement including a lower fee per kWh and a restriction on the generation capacity. Before operation, a sales contract was established to sell the electricity. For the generated heat, the idea was to use it for warming a future residential area nearby but this has never been realized. Digestate was processed into a solid and a liquid fraction. The solid fraction was transported to a French fertilizer trader. For the liquid fraction, there was a promise by the national government allowing to spread it on the land in the region. The idea behind this digestate processing was to reduce transport movements. However, two years later than it was planned (2009 instead of 2007) spreading became allowed. At that time, a pilot was started to analyse the liquid fraction on its mineral contents (Velthof, 2011). Consequently, before spreading was allowed (time span of 2 years), disposal costs (15 euros per ton) had to be paid to get rid of the liquid fraction as the latter was treated as animal manure. These developments caused high unexpected extra costs. Another unexpected cost happened at the input side, prices of co-products like maize, brewer's spent grain and flower bulbs rose dramatically due to increasing demand. There was also competition of demanders from neighbouring countries. Often those demanders had the possibilities to pay a higher price for the biomass because they got higher subsidy payments from their national governments. Also nationally there was no level playing field due to differences in subsidy payments (MEP versus SDE subsidy programme). Summarizing, according to the interviewee, there were three important factors causing the necessity to offer the plant for sale:

- Weak coordination and supervision at national policy level, especially for the digestate processing and getting the agreement to use digestate a substitute for artificial fertilizer;
- High prices of co-products;
- Sales of the digestate in The Netherlands.

6.3 Economic and institutional factors

Based on all information we have gathered, including the interview held, about Biogreen and the economic and institutional factors described in previous chapters, we perform an analysis on the role of these factors in this case study.

Asset specificity. The interviewee indicated the *site specificity* to be important. As the manure was attracted from 50 different suppliers (members of the cooperative) the location was chosen in such a way that it had a distance of maximal 10 kilometres from each member in order to minimize transport movements. Further it was expected to sell the liquid fraction to farmers in the Salland, Veenkoloniën and IJsselmuiden regions, all relatively close to the plant. Another concern was the *human asset specificity* related to the production of biogas. For this, a five-year contract was made with a biologist for supervision; every week a sample was sent for analysis of the digestion menu. This resulted in high methane yields guaranteeing full MEP subsidy payments. A more problematic aspect was the processing of the digestate into a solid and a liquid fraction, a high *dedicated asset specificity*. There were problems with exporting both fractions due to failing techniques: thickening the solid fraction turned out to be problematic resulting in extra costs and for the liquid fraction farmers applying it were complaining about the nitrogen and potassium values (Boerderij, 2011b). Finally, *physical asset specificity* seems to be present because the assets have a narrowly defined use. More detailed, when separating the biogas plant into a biogas production part and a digestate processing part, the biogas production assets can only be used to produce biogas. Another application of the biogas production assets could be the function of a silo, storing manure but this cannot be marked as a valuable alternative for biogas production. For the digestate processing part, an opportunity could be to process manure instead of digestate. Whether this alternative is also realistic for economic and technical reasons is not known.

Uncertainty. Biogreen has been confronted with different *market* uncertainties. At the markets for co-products, increasing (cross-border) demand caused upward price movements over time. The interviewee mentioned a few examples of this (see Appendix I). This development combined with the price inelasticity characteristics of agricultural markets gave high uncertainty: instable prices and demand can lead to large fluctuations in profitability. At the output side, electricity was expected to be sold at 8 cents per kWh. However, due to lower electricity market prices an agreement was made to sell one kWh of electricity at 5.5 cents (Boerderij, 2011b). Also uncertainties about *technologies* were present. In addition to electricity, the CHP also generated heat. There were plans to use the heat for warming a residential area nearby. For this case, a biogas-pipeline of 7 kilometres length carrying biogas was needed to be build and a replacement of one of the CHPs to the location where the pipeline would end. However, realising these ideas appeared to be too difficult (Boerderij, 2011b). A similar but successful project is located in Zeewolde (IEA Bioenergy Task 37, 2011). Besides outputs generated out of biogas, digestate processing delivered two fertilizers. One of them, the solid fraction, faced problems with thickening. Due to technical failures, the fraction did not meet the export requirements and therefore had to be disposed against high costs. For the liquid fraction, the mineral content did not satisfy the users (Boerderij, 2011b).

Government policy. The business plan of Biogreen was partly based upon receiving the MEP subsidy. After the construction phase was started (foundation), the Dutch government announced to stop with providing MEP subsidies, a new more cost-effective subsidy programme would come. At that moment the grant was still not fully approved. Without, it was impossible to get the biogas plant economic feasible. After this notification, lobbying activities started to secure the subsidy payment and this finally resulted in receiving a transitional arrangement including a lower free per kWh and a restriction on the generation capacity. Consequences of this *time-inconsistency* were besides worsening the financial conditions, also a delay of the construction period of the biogas plant with a year. Another consequence of government policy actions is the absence of a *level playing field*. The interviewee stressed the point that due to differences in regulation among countries and different subsidy programs within The Netherlands particular competitors have more possibilities or more money to spent to buy e.g. biomass than others. The list of allowed biomass for co-digestion of manure differs among countries. According to the interviewee, this led to a situation in which Dutch flower bulbs were transported to Belgium because they were not allowed to be digested in Dutch biogas plants. With respect to differences in subsidy payments, an example was mentioned where it appeared that a German biogas plant owner could afford to pay more money than Dutch competitors to obtain the maize they wanted to buy.

6.4 Conclusions of this chapter

Different types of asset specificity have been identified in this case study. For some of them there was a solution, such as for the location (site specificity) and the digestion process (human asset specificity). For others, this was not the case and the consequences of that were high. Both export products coming off the digestate processing did not meet customer expectations for different reasons (dedicated asset specificity) leading to extra costs. The high physical asset specificity became apparent when the plant went bankrupt and the take-over had to be done rapidly due to its narrowly defined use.

There were also different types of technological uncertainties present. Especially for the digestate processing, uncertainty was high. In addition market uncertainties proved to be present: upward price movements at biomass markets and a lower kWh payment were not expected. More uncertainties came from the side of the government. The MEP subsidy payment was aborted and only a transitional arrangement was granted. Differences in regulation among countries and different levels in subsidy payments resulted in a loss of competitiveness especially in biomass markets. Finally, regulations regarding manure (digestate) processing were incomplete; allowance to sell the liquid fraction as 'green fertilizer' via a pilot was postponed for two years. At this moment, it seems that the national government is willing to shape new conditions with relation to this topic (Ministerie van EL&I, 2011b).

Chapter 7: New developments

Starting the MEP subsidy programme in 2003, the national government stimulated renewable energy production originating from biomass, hydro power, solar and wind. In the agricultural sector, this government policy stimulated initiatives to start-up biogas production using co-digestion of manure techniques and the CHP technique to utilize biogas into electricity (and heat). Most biogas plants nowadays use these techniques. However, they often are not profitable for different reasons (Gebrezgabher *et al.*, 2010; Peene *et al.*, 2011; Rabobank, 2011). In this research several factors have been indicated for this, like the high uncertainties and consequences of government policy actions. Another point of interest is the way how digestate is used. When co-digestion of manure is applied, according to EU regulations produced digestate is specified as animal manure. The characteristics of the current Dutch manure market, excess supply and price inelasticity, result in a situation in which a biogas plant owner has to pay extra costs to dispose digestate as animal manure. The case study with Biogreen has confirmed many factors to be important. Nevertheless, biogas production has been put on the agenda.

In this chapter, we would react to two recent developments: the changed design of the latest subsidy programme SDE+ and the announcement of manure policy reforms. Both developments can cause major changes for the Dutch biogas sector. In section 7.1 we first describe characteristics of new biogas projects looking to actual SDE+ subsidy grants. Then in section 7.2 we describe the new manure policies coming up. Subsequently, in section 7.3 we pose the idea that biogas production could go hand in hand with suggested manure processing. Using the LP-model of Gebrezgabher *et al.* (2010) in section 7.4 we simulate three scenarios to analyse possible consequences of the new manure policies. Section 7.5 concludes.

7.1 SDE 2011 subsidy grants

The latest subsidy programme, the SDE+ subsidy, promotes renewable energy production using a feed-in tariff to compensate for the difference between producing ‘grey’ energy and ‘green’ energy for 12 or 15 years. The subsidy programme is designed as follows (Agentschap NL, 2011c):

- One integral budget ceiling: all kind of technologies that produce renewable energy are supported; they all compete with each other for getting a subsidy payment. For 2011 only, the budget will be divided into an electricity and a green gas part.

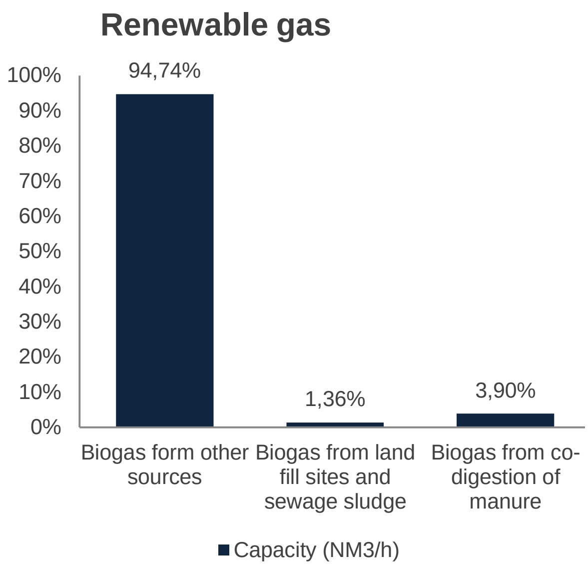
- Subscribing at different demanded subsidy levels: candidates apply for the lowest feed-in tariff of 9 cents/kWh or 62 cent/Nm^3 or at a level of every time two cents per kWh or 14 cents per Nm^3 higher. The highest level of subsidy is 15 cents/kWh or 104 cents/Nm^3. This way a demand equation for subsidy is constructed. Given a fixed total budget we get a market equilibrium. So we have a kind of auction system at each subsidy level which give the most efficient technologies or largest projects (scale advantage) the highest change of getting a subsidy payment.
- Maximum feed-in tariff: 15 cents/kWh or 104 cents/Nm3 is the maximum amount paid. Technologies which cannot produce renewable energy supported by this feed-in tariff of 15 cents or lower deserve no consideration.
- Free category: innovative entrepreneurs who can produce renewable energy with a feed-in tariff less than 9 cents/kWh or 62 cents/Nm^3 can apply for a SDE subsidy payment indefinitely in the first subsidy level (extension of the auction system). In the next subsidy level category entrepreneurs can apply for a payment less than 11 cents/kWh or 78 cents/Nm^3 etc.

In previous subsidy programme designs, for each renewable energy category there was a budget available while in the current SDE+ subsidy programme, a design is created that stimulates competition between different categories. The main reason for this approach is that the national government wants to meet the goals for renewable energy use targets set by the European Union in a cost-effective manner. Due to the principle of first-come, first-served with a budget ceiling, almost the whole budget is allocated to subsidy requests done in the first level. It seems that this approach is successful since 85% of the requests in the first level is done in the free category (Ministerie van EL&I, 2011a). This means that those initiatives expect to produce renewable energy with support less than 9 cents per kWh or 62 cents per Nm^3.

The most favoured option among all categories is to upgrade biogas to natural gas methane contents. Up and till now, almost 70% of the whole budget goes to renewable gas projects with a total worth of 942 million euros. Almost 13% (173 million euros) of the subsidy payments is reserved for biogas production projects to generate renewable electricity. The remaining part is for wind and solar projects (AgentschapNL, 2012).

In figure 7.1 an overview is provided of subsidy grants for biogas production categorized by type of energy produced and technique used. Within the renewable gas category almost 95% of the promised biogas production will come from ‘other sources’. Within the renewable electricity category this share is almost 64%. In this category, biogas is produced out of waste streams originating from the food and beverage industry or biofuel production industry

(Lensink *et al.*, 2011). Together they will get a subsidy amount of 966 million euros which is almost 71% of the whole budget (AgentschapNL, 2012).



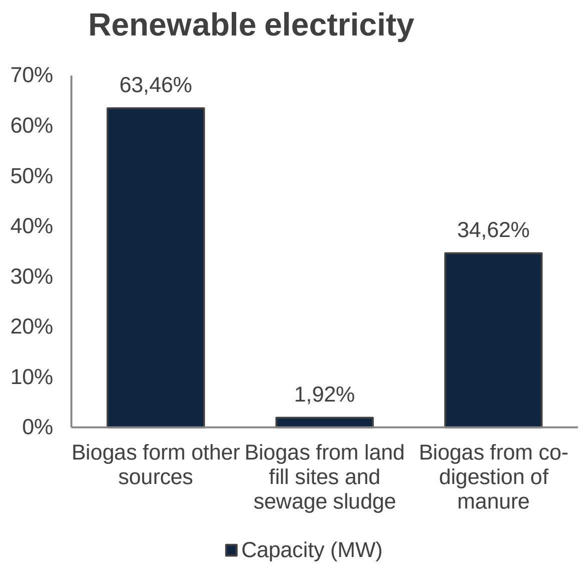


Figure 7.1: Grants permitted under SDE+ (2011) for biogas production categorized by type of energy produced and technique used (Source: AgentschapNL, 2011b).

From this it becomes clear that future biogas production will be done with ‘other sources’ and most utilization concepts can be contributed to renewable gas production. Which biomass exactly will be used is not exactly known, however, the trend seems to be that less animal manure is digested. Moreover, applying co-digestion of manure becomes more and more difficult as those high energetic biomass streams will be digested separately. Detailed information about each subsidized biogas project is lacking but it is realistic to expect that especially large-scale projects now get the payments, using own waste streams as input for biogas production.

7.2 Manure policy reforms

The consequences of new adopted manure regulation can be high: new manure legislation in 2006 resulted in a price increase of 30% for poultry manure and up to 400% for pig manure because supply of animal manure increased (De Hoop *et al.*, 2011). Due to its price inelastic characteristics, the price of animal manure had to go up to bring demand and supply together at the market. For poultry manure a solution was found: the Moerdijk power plant uses thermal conversion techniques to process the manure into energy resulting in a 25% price decrease of poultry manure (De Hoop *et al.*, 2011). Nonetheless, manure legislation is needed to restrict mineral surpluses in order to prevent environmental harm.

Nowadays, environmental quality has improved but there still is a manure surplus present. Wilt and Boosten (2011) indicate some market failures:

- Suppliers and demanders of manure don't know each other. In the agricultural sector, potential demand for processed manure products (fertilizers) is not recognized;
- The problem of free-riders and the focus on liquidity make constant supply of manure difficult. This affects the reliability of supply;
- Manure is valued as waste. Farmers with excess supply pay disposal costs to get rid of it. The market is looking for short-term solutions to guarantee sufficient liquidity. Long-term solutions stay constantly under pressure and livestock farmers don't commit themselves to structural solutions;
- According to current manure regulations, processed manure products still fall under the restrictions of manure and waste legislations. This restricts the use and application of those products, particularly in non-agricultural sectors.
- Facilities for manure processing are fairly small-scaled in comparison with total supply of manure and high demand for processed manure products. Existing solutions are mainly singular solutions, like digestion or production of substitutions for artificial fertilizer. Combinations of those solutions are seldom made.

Suggested manure policy reforms (Ministerie van EL&I, 2011b) seek for a solution for the excess manure supply problem, based on the expectation that demand for fertilizers will increase in future. In the next decades, even scarcities at the market for manure are expected. Besides, the current market conditions for manure hinder reaching the (environmental) objectives, also set by the EU (Ministerie van EL&I, 2011b). The national government is looking for a new policy that will help in the transition from excess supply to a market with scarcities. The proposal consists of three pillars: a new system for balancing production and demand of manure, removal of redundant mineral quantities in feed and production of 'green fertilizers'. With respect to the first pillar, the system consists of two important rules: part of the manure must be processed through certified agencies (e.g. a biogas producer also having manure processing equipment) and for the remaining excess manure disposal must be planned. The suggested obligation of processing part of the manure has to do with the price inelastic characteristics of the Dutch manure market. According to De Hoop *et al*. (2011), manure processing in the Netherlands is not very successful because innovations for processing manure involve risks to entrepreneurs as manure processing will lead to lower manure prices implying that 'free riders' will lift on the success of those innovations. Furthermore, there is much uncertainty regarding legislation. With respect to the last pillar, mineral concentrates – like in the case study Biogreen produces – are still treated as animal manure. The national government will start lobbying to gain recognition that mineral concentrates can function as 'green fertilizer' and form an alternative for artificial fertilizer. This can reduce uncertainty and therefore stimulate innovations.

7.3 Anaerobic digestion as entrance portal

Processing manure can easily be accompanied with anaerobic digestion of manure as a preliminary process to obtain biogas. The latter can be transformed into electricity (and heat) using a CHP unit or refined so that the methane (CH_4) percentage becomes equal with normal gas. Today there is a lively discussion going on which biogas utilization reaches the highest energetic efficiency rate. Current biogas plants mainly use CHP-techniques to generate electricity while heat is often not used for various reasons. This particular utilization will not reach high energetic efficiency rates since only electricity is sold. When the heat can be used for valuable purposes, then the energetic efficiency rate reaches values which exceeds the rate of upgrading biogas to natural gas (Bekkering *et al.*, 2010; Projectgroep Biomassa & WKK, 2012). However, it seems that upgrading biogas now is the favourite option given the high amount of subsidy grants reserved for renewable gas projects. But if anaerobic digestion of manure and manure processing (digestate) are combined, the best option is to use biogas for generating electricity and heat. Assuming that heat can be fully used for processing stages, the highest energetic efficiency will be reached using a CHP.

Animal manure can be a valuable resource for renewable energy production and a source of nutrients for agriculture. The ideas proposed by the new manure policy reforms (obligatory manure processing and production of ‘green fertilizers’) fit in the idea of combining anaerobic digestion of manure with manure processing potentially resulting in some benefits (Holm-Nielsen *et al.*, 2009):

- anaerobic digestion of animal manure results in a reduction of greenhouse gas emissions by capturing especially methane;
- anaerobic digestion of animal manure produces biogas which can be transformed into renewable energy;
- manure (digestate) processing can be processed into valuable fertilizers, like a liquid fraction rich in nitrogen and potassium and a solid fraction rich in phosphates.

In reducing the manure surplus present in The Netherlands, processed fertilizers can be exported to e.g. areas outside the country with phosphate shortages (solid fraction) and compete with artificial fertilizers (liquid fraction). Both will lower the manure surplus by reducing the amount of minerals and this in addition will lead to less environmental harm.

7.4 Manure processing costs analysis

Despite its bankruptcy, the Biogreen biogas plant (see chapter 6 for a detailed description of the plant) can serve as an example to illustrate the idea for combining anaerobic digestion with manure processing. One point of interest is to look at possible consequences of suggested manure policy reforms regarding the input costs of manure for biogas production, current disposal costs and expected earnings from processed fertilizers (solid and liquid fraction). Therefore, three scenarios are formulated representing current and future expected circumstances due to changing manure policies from the viewpoint of a biogas plant owner. In this case, the biogas plant owner does not have his own manure sources like a livestock farmer has. This viewpoint is in line with the current situation of Biogreen.

- **Scenario One (default)**. In this scenario we will simulate the current situation. At this moment animal manure is negatively valued and high disposal costs have to be paid to get rid of it. However, gate fees are received when animal manure is delivered to be digested. In the model, for each ton of pig manure 11.5 euro is received (not including transport costs). After biogas is produced out of the manure, digestate is processed into a solid and a liquid fraction. It is assumed that the solid fraction is exported at a price which only compensate for transport costs. But for the liquid fraction, current legislations do not allow to sell it as a 'green fertilizer' and consequently disposal costs of 20 euro per ton (not including transport costs) have to be paid since it is only valued as animal manure.
- **Scenario Two**. Intermediately, the liquid fraction is treated as a substitute for artificial fertilizer. Manure processing initiatives have led to a lower pig manure price and therefore also a lower gate fee. The latter has dropped to 8 euro per ton. The solid fraction has gained more recognition and now it can be sold for 2 euro per ton. For the liquid fraction some users are found who are willing to test the fertilizer for its usage. Only transport costs are compensated for (3 euro per ton).
- **Scenario Three**. In the long run, further manure processing applications have solved the excess manure problem and therefore the gate fee has dropped to 2 euro per ton. Both fertilizers now are commonly accepted and used, and hence are sold at 5 euro per ton each.

The simulations are carried out with the LP-model of Gebrezgabher *et al.* (2010). In this simple analysis we only look at the differences between the gross operating result after running the three formulated scenarios. No changes are made with respect to technical issues, such as biomass proportions and methane yields. (For a more detailed description of the model, see Appendix II.)

In the model, we only look at pig manure price changes. The biogas plant also uses poultry manure as input but this is just 9% of total biomass. Furthermore, in the model the liquid fraction can be transported to three regions nearby. For these regions, available land per crop type is specified and also the mineral requirement for each crop. In scenario 1 where the liquid fraction is only treated as animal manure it is assumed that only arable farmers can buy it while in the other scenarios, after the legislation has been changed, arable as well as dairy farmers buy the 'green fertilizer'. This specification ultimately has an effect on transport costs. For the solid fraction it is assumed that everything is exported to no further specified areas (Gebrezgabher *et al.*, 2010).

Table 7.1: Economic results (x € 1000,-) for three scenarios simulating possible future consequences of changing manure policies

Scenario	One (default)	Two	Three
	At present	*Intermediate run*	*Long run*
Price pig manure (gate fee)	11,5	8	2
Price solid fraction	0	2	5
Price liquid fraction	-20	0	5
Total biomass costs (including gate fees)	-234	-62	234
Sales solid fraction	0	17	43
Sales liquid fraction	-207	0	52
Gross operating result	**2050**	**2141**	**1922**

In table 7.1 the economic results are presented for the three simulations. In the default scenario, the negative value of total biomass costs is caused by the substantial revenues the plant receives from the gate fees of pig manure. These revenues even exceed the remaining costs for buying biomass. With respect to the fertilizers, the liquid fraction is not treated as 'green fertilizer' and that is why the plant has to pay high disposal costs for it.

In the second scenario, as a result of increased manure processing facility realisations, the price of pig manure has gone down due to less excess supply. That is why the gate fee also has gone down and consequently the negative value of total biomass costs has become smaller. Nevertheless, high disposal costs do not have to be paid anymore for the liquid fraction and this outweighs the lowered gate fee. The gross operating result is higher than in the default scenario.

In the final scenario, as a result of the solved excess manure supply problem, the low gate fee for pig manure now gives high total biomass costs. Despite the increased revenues coming from the sold fertilizers, the increased total biomass costs lower the gross operating result.

An interpretation of this is that the gate fees received by the animal manure intake is over a large amount in kilograms while the revenues of the sold fertilizers is over a small amount in kilograms. Due to the processing of the digestate, the quantities in absolute terms reduce largely. Therefore, a price change for gate fees has a much larger effect on final earnings than a price change for the produced fertilizers.

7.5 Conclusions of this chapter

In this chapter, two new developments have been discussed which both can influence the performance of the biogas sector. New subsidy grants mainly go to renewable gas projects and within this category, particularly other sources of biomass will be used for biogas production than animal manure. For current biogas plants, mainly using animal manure and co-products, it becomes increasingly difficult to afford good quality co-products as those biomass streams will be digested separately.

When suggested manure policy reforms become real and manure processing projects structurally will be established, the price for pig manure will decline. The consequence is that gate fees also become lower and therewith revenues. Another consequence is that if the policy reforms will be realized there is the possibility to sell the liquid fraction as ‘green fertilizer’ instead of paying high disposal costs to get rid of it. The result of the simulations reveal that the possibility to sell the ‘green fertilizer outweighs the lowered gate fees and therefore gives an increased gross operating result. In the long run when gate fees further decrease, input costs can rise dramatically. Despite increased earnings of fertilizer sales, the gross operating result then considerably declines.

Chapter 8 Conclusions and discussion

Conclusions

In this section we evaluate whether the research objective has been realised. It was formulated as: 'The objective of this research is to identify the economic and institutional factors affecting the financial feasibility of biogas production in The Netherlands. Five research questions were formulated to structure the analysis.

First two research questions assessed some elementary aspects of biogas production and its different applications in the Dutch biogas sector, and stakeholders involved in the production and use of biogas. In answer to the first question, biogas is produced out of organic materials in an oxygen-free environment. This spontaneous process is applied on different sources of organic materials to produce biogas. The growth of biogas production in The Netherlands is mainly caused by co-digestion of manure in the agricultural sector, animal manure together with high energetic biomass is digested in order to produce biogas. The latter is mainly utilized for producing renewable electricity. For the reason that most biogas is produced within the agricultural sector, we restrict the analysis to co-digestion of manure projects. As a next step, a stakeholder analysis was executed. Here it became clear that before construction of a plant, nearly all stakeholders, both public and private, preferably should co-operate to prevent future failures, like insufficient supply of inputs at time of operation or NIMBY behaviour of neighbours at the start of the project.

In the next parts of the research, economic and institutional factors were identified, partly based upon a transaction cost economics approach. Among others, the high uncertain environment is a main concern. Uncertainties with respect to markets, technologies and government policy are highly present. Another issue is the high transaction specific investments made for biogas production. Also some market failures have been identified which possibly justifies government intervention. Based on the concept of normative and cognitive institutions (as an opposite of regulative institutions) we identified a missing common vision how to operate and a public concern touching upon the ethical aspects of biogas production when certain types of biomass are used. In answer to the fourth research question, we analysed the transaction characteristics to see which governance structure fits best in a biogas supply chain. With respect to human behaviour, a more specified governance structure is preferred due to the complex environment for the decision-maker (bounded rationality notion) and the threat of opportunistic behaviour of other actors. With respect to the transaction attributes, a hybrid governance structure is preferred due to the high uncertainties present, the substantial transaction-specific assets and low frequency rate of transactions.

By means of a case study, the economic and institutional factors identified so far were empirically analysed for their presence. The outcomes of the case study revealed that high uncertainties were existing, especially regarding government policies, markets for high energetic biomass and techniques used. Uncertainty about government policies mainly had to do with legislation related to manure policies. Looking at the transaction-specific assets, different forms of asset specificity were present. For some of them there was a solution, for others no solution was present leading to negative financial consequences.

Found results hitherto gave rise to discuss two new developments coming up: the new subsidy programme (SDE+) for renewable energy production and ideas proposed for reforming the existing manure policies. Both developments were discussed to see whether they influence the current biogas production activities mainly concentrated in the agricultural sector. As a consequence of the new subsidy programme design, competition and budget ceiling, large biogas projects apply for subsidization using valuable high energetic biomass owned by the investors (i.e. food industry). Co-digestion of manure projects cannot compete against these large projects for subsidy. For current co-digestion of manure plants, high energetic biomass inputs will become less available and therefore further weaken the financial feasibility. Regarding the second development, when suggested manure policy reforms will become real, in the intermediate run it is expected that this will have a positive effect on the financial feasibility of biogas plants using co-digestion of manure. This is caused by the improved sales opportunities for the digestate that can be used as a substitute for artificial fertilizer. However, gate fees which are paid at the intake moment of animal manure will decline. In the long run, when it is assumed that gate fees further decline, the effect of lower gate fees outweighs the increasing sales opportunities for the digestate and finally will give lower financial results.

Discussion

This research has indicated many economic and institutional factors that affect the financial feasibility of biogas plants. The case study subject, the Biogreen biogas plant has confirmed many of these factors to be present. However, we must inform the reader that the case study is not representative for the current biogas sector due to its large scale and advanced processing equipment for digestate.

At the same time, the case study shows that biogas production in agriculture can fulfil different goals set by governments. On the one hand, the EU and national goals for renewable energy and greenhouse gas emissions reduction, on the other hand the excess of animal manure in The Netherlands. For renewable energy production and greenhouse gas emissions reduction, the subsidy programme SDE+ subsidizes renewable energy projects. For lowering the excess of manure problem by stimulating the production of 'green fertilizers'. This also will lower greenhouse gas emissions e.g. through less transport movements and lower artificial fertilizer use.

Under current conditions, many publications (Gebrezgabher *et al.*, 2010; Peene *et al.*, 2011; Rabobank, 2011; Wilt and Boosten, 2011) and this research conclude that current plants, using co-digestion of manure techniques and utilizing biogas to produce electricity, make losses or even go bankrupt. There seems to be no common vision about which goals should be satisfied. Is it to produce renewable energy only? If yes, than another perhaps better option would be to subsidize biogas projects outside agriculture because it seems they can produce biogas against lower costs. In fact, this is what is happening at this moment looking to the actual subsidy grants. Is it to produce fertilizers in isolation or in a combination with renewable energy? The case study subject combined all those goals, but failed.

Suggestions for new research therefore would be to critically assess the options for biogas production in agriculture. Which goal(s) should biogas production in agriculture fulfil? Should we change therefore our focus towards other techniques for biogas production, like mono-digestion of animal manure? Is it possible to combine biogas production in agriculture with manure processing? To what extent is government intervention needed?

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Appendix I –Interview Biogreen (Dutch)

De belangrijkste economische en institutionele succesfactoren voor het welslagen van biogasproductie in Nederland

Interview met Dhr. J.G. Schokker, voormalig voorzitter van coöperatie Biogreen

Wat was de aanleiding om een biogasinstallatie op te zetten?

Nederlandse varkenshouders lopen op alle concurrentiefronten in de pas met concullega 's van andere Europese landen alleen is hier het mestprobleem. Een biogasinstallatie geeft warmte en stroom en geeft ook de mogelijkheid om mest te verwerken, om mineralen af te zetten in het buitenland waar vaak een tekort aan mineralen is. Een ander punt is ook duurzaamheid van de varkenssector.

Wie heeft er allemaal meegewerkt aan dit project, wie waren de belanghebbenden?

Gemeente, provincie, LNV, SenterNovem, GIBO (business plan), klein adviesbureau Landmark projecten (subsidie aangevraagd), energiemaatschappij, Schmack Biogas (operationele proces)

Waarom een coöperatieve structuur?

In de mestwereld wordt veel geld verdiend in de handel (blinkende vrachtwagens). Het is daarom beter om dit verhaal in eigen hand te houden. En verder, terwijl er op veel plaatsen een mineralentekort is, hebben wij hier mineralen genoeg. Door de mest te bewerken, kunnen we zelf 'groene' kunstmest maken en dat gebruiken in onze eigen regio.

Heeft u een subsidie aangevraagd? Zo ja, welke?

MEP in eerste instantie, 9,7 eurocent per kWh. Verder ook een innovatiesubsidie (SenterNovem) om een deel van de investeringen voor mestverwerkingsinstallatie te bekostigen.

Vanaf wanneer was die subsidie in beeld bij de investeringsplannen? (Met andere woorden, heeft de subsidie bepaald hoe het biogas benut werd?)

Bijzonder verhaal. We hadden een MEP-subsidie aangevraagd voor een vergoeding per kWh, maar toen kreeg de minister het idee om te stoppen met de MEP-regeling. Toen we nog maar net begonnen waren met de fundering van de biogasinstallatie, kregen we te horen dat de MEP niet doorging. De Rabobank in grote paniek. Op dat moment hebben we alles op alles gezet om nog in de overgangsregeling te komen. Dat heeft ook nog weer een jaar gekost met alle (financiële) gevolgen van dien.

Was er onzekerheid over de toezegging van de subsidiestroom voor uw investering? Wat als de subsidie niet toegezegd zou worden?

Zie vorige vraag, ja, er was veel onzekerheid. Subsidietoezegging is ter nauwer nood goed gegaan. De overgangsregeling had wel slechtere voorwaarden waardoor het kostprijstechnisch weer minder interessant werd. De opwekkingscapaciteit (1,8 MW) mocht niet verder uitgebreid worden. Het getal van 1,8 MW is naar huidige maatstaven ook niet zoveel.

Wanneer de subsidie niet toegezegd zou worden was er een groot probleem, want dan hadden we 'groene' stroom moeten produceren tegen een 'grijze' prijs. Dat is eigenlijk onmogelijk. Op dit moment draait er geen installatie zonder subsidie; dat is in Nederland onhaalbaar.

Wat zou er met het verkregen biogas gedaan worden? (Bijvoorbeeld WKK: elektriciteit en warmte, opgezuiverd naar groen gas.) Waarom is voor deze toepassing gekozen? (Als WKK, navragen of alle warmte werd gebruikt.)

In 2002 zijn we begonnen. Er was nog geen mogelijkheid om het biogas op het gasnet te doen. De overheid, de netleverancier, etc. waren zover nog niet. In onze plannen werd het biogas gebruikt voor het opwekken van elektriciteit en warmte. Er waren ook plannen om de warmte te gebruiken om huizen te verwarmen verderop in een nieuwe woonwijk in Deventer door een buis te leggen van 7 kilometer lang, zodat de restwarmte volledig benut zou worden.

Wat zou er met het verkregen digestaat gedaan worden? Waarom is (zijn) voor deze toepassing(en) gekozen?

Digestaat zou verder bewerkt worden omdat we vonden dat de mineralen van de markt moesten (zie eerste vraag). De helft van het digestaat werd opgeschoond tot water zodat dat het riool in kan. Bijkomend voordeel is reductie van transportvolumes. We hadden ook het Cradle-to-Cradle-concept toegepast: alle mineralen in Salland geproduceerd moeten ook weer in de Sallandse bodem terechtkomen. We wilden niet afhankelijk zijn van akkerbouwers. Dan komen we ook van de discussie af van 'dat alle mineralen binnenkomen via Rotterdam'.

Heeft u achteraf gezien voor de juiste toepassingen gekozen? (Zowel voor methaan als digestaat.)

Met de kennis van toen wel. Er was nog niet de mogelijkheid om het biogas te zuiveren voor op het gasnet. Maar aan de andere kant, de filosofie die we besproken hebben, die klopt naar mijn idee nog steeds: het project leverde groen gas, groene stroom, groene warmte en groene kunstmest op en de inputs waren mest en co-producten.

Met welke publieke instanties heeft u te maken gehad? Hoe verliep die samenwerking? Ook met betrekking tot het verstrekken van vergunningen?

Gemeente en provincie hebben heel goed meegewerkt. Het waterschap werkte tegen; het bleek lastig om een vergunning voor het lozen van water te krijgen. Dit heeft 1,5 jaar geduurd. Uiteindelijk, met hulp van de gedeputeerde van Overijssel is dit opgelost.

Landelijk was het lastiger. Het beleid en de praktijk zitten ver uit elkaar.

Het vervoeren van de grondstoffen (zoals mais) en producten (zoals digestaat) brengt hoge kosten met zich mee; de locatie o.a. is daarom erg belangrijk. Heeft u ten tijde voor de investering daar rekening mee gehouden?

We hebben gekeken in Salland naar een locatie waar in een straal van 10 kilometer, 60.000 kuub beschikbaar is. Dat was het geval in Heeten. Door daar de biogasinstallatie neer te zetten, zou het transport nooit meer dan 10 kilometer zijn. Voor de meeste locaties waar de mest vandaan kwam was dit 3 à 4 kilometer.

Ook hebben we gekozen voor een loonwerkbedrijf, zodat we – in geval van dierziektes – uit de buurt zitten van die stallen.

Verder was het doel om van het digestaat alleen de groene kunstmest te hoeven transporteren naar afzetgebieden. 50 procent van het digestaat zou worden verwerkt tot water wat het riool in gaat. Het overige is een dunne en dikke fractie mest. De dikke fractie met fosfaat gaat naar andere gebieden, de dunne fractie met kalium en stikstof wordt afgezet in de omgeving ter vervanging van de kunstmest. Hierdoor neemt het transportvolume drastisch af.

Was ten tijde voor de investering al afgesproken wie de producten zou afnemen? Waren er meerdere afzetmogelijkheden?

Voor de digestaattoepassingen was er een spontaan contact ontstaan via een van de leden met een Franse meststoffenhandelaar, de droge fractie ging naar wijnboeren in Frankrijk. Maar dit product kun je ook wel in Duitsland afzetten. Dat is geen probleem.

Voor kunstmest hadden we de toezegging om dat te kunnen exploiteren in de regio (twee jaar later dan gepland omdat daar toestemming van hogerhand voor nodig was).

Elektriciteit waren meerdere gegadigden voor. Vijf partijen hadden zich ingeschreven; met hen hebben we onderhandeld.

Warmte zou naar een toekomstige woonwijk gaan. Essent had in Deventer twee leegstaande ketelhuizen waar onze WKK’s zo ingezet konden worden om warmte te produceren. We hebben ook nog gekeken naar afzet van warmte voor een plaatselijke bejaardencentrum. Maar hier konden andere partijen niet aan meewerken.

Hoe kreeg u beschikking over de te vergisten (co-)producten? **(Via eigen inbreng, contracten, markt, etc.)** **Speelde de regelgeving hierbij een rol?** **(De 'witte lijst', minimaal 51% mest)**

Deel via eigen inbreng, deel via handelaren. Er zijn maar een aantal grote partijen die handelen in co-producten, via o.a. bierbrouwerijen.

De witte lijst speelt een belangrijke rol. Op het moment dat een product op de witte lijst komt wordt het twee keer zo duur. Hier verdient de handelaar aan.

De verschillen tussen landen met betrekking tot de toegestane co-producten zorgt voor rare ontwikkelingen. De bloembollen hier uit de buurt gaan naar België omdat ze hier niet de vergister in mogen. In Nederland is in onderzoeken naar toegestane co-producten andere conclusies getrokken dan in buurlanden. Gevolg: brood mag er in Nederland niet in, maar in andere EU-landen wel. Mensen mogen brood eten, dieren mogen brood eten, maar een vergister die dan in veel grotere getale brood 'eet' overschrijdt dan een norm en wordt als gevolg brood niet toegestaan als co-product. De manier hoe het onderzoek opgezet is, bepaalt wat wel en niet mag.

Was er concurrentie voor de grondstoffen? Heeft u ook te maken gehad met concurrentie vanuit het buitenland (Duitsland, België)?

De prijs voor een co-product, bijvoorbeeld door Orenzo (juiste naam?), wordt bepaald door vragers vanuit meerdere landen. Gevolg: als een Duitse boer direct naar € 120,- gaat, moet de Nederlandse boer mee. Er is dus veel concurrentie. Maar dit is ook het geval voor de maisprijs. Als deze in Duitsland omhoog gaat, voelen wij dat ook. Een Duitse boer heeft meer subsidie, die kan er dus ook meer voor betalen.

Als de grondstoffenmarkt hogere prijzen laat zien, gaat de markt voor reststromen daarachteraan; op het moment dat er weinig graan is, wordt de bierbostel ook duurder.

Hoe verliep het operationele proces? Wie was verantwoordelijk? Was diegene ook vertrouwd met anaerobe vergisting? Wist diegene hoe de CH_4-opbrengst te maximaliseren?

Dat hadden we goed afgedekt. We hadden een vijfjarig contract afgesloten voor begeleiding van de vergister. Daar hadden we een bioloog voor aangenomen. Elke week stuurden we monsters op. We kregen advies terug met betrekking tot de samenstelling van het vergistingsmenu. Dat proces ging erg goed.

Wat zijn volgens u de belangrijkste redenen waarom uw biogasinstallatie en –verwerking niet rendabel werden?

- Er was geen coördinatie (op nationaal beleidsniveau) in dit soort trajecten die de supervisie neemt. Met name de concretisering van de ideeën voor digestaatverwerking heeft veel te lang geduurd.
- Co-producten veel te duur.
- Afzet van digestaat in Nederland is een knelpunt.

Toen kwam het moment dat de Rabobank zei dat we er professioneel management op moesten zetten en een professionele inkoop- en afzetorganisatie. Op dat moment is de heer Nieman in beeld gekomen, die al meerdere installaties heeft. Deze kon bij wijze van spreken een *schip vol glycerine inkopen, terwijl wij slechts een vrachtwagen vol. Dat is de richting die Rabobank* ons ingestuurd heeft.

De investeerder zou dan de biogasinstallatie overnemen met de lusten en lasten, en wij varkensboeren konden mest aanleveren voor € 11,- per kuub + € 2,- transportkosten voor 8 jaar lang. Maar Nieman kreeg de rentabiliteit ook niet omhoog en zo is de vergister uiteindelijk failliet gegaan. Henk Nieman heeft vervolgens de installatie weer teruggekocht van de Rabobank en is weer doorgestart.

Het nieuwe mestbeleid lijkt wel door te gaan op het idee wat wij eigenlijk bedacht hebben: mestverwerking verder ontwikkelen om zo van het mestprobleem af te komen.

De hele trein, de coördinatie, daar heeft het gehaperd. In onze formule zat alles wat de politiek wilde: het Cradle-to-Cradle-concept, mest; een waardevolle grondstof, groene stroom, groene warmte, groene kunstmest, beperking van het transport van mest.

Appendix II - Description of the LP-model

The basic structure of the modelled biogas plant has the form of a standard linear programming (LP) model. In such models, the goal always is to maximize (minimize) a defined linear objective function subject to a number of linear equality and linear inequality constraints. All defined constraints shape a feasible region. Next, the objective function is maximized when that point in the feasible region is found which gives the highest value.

To explain how the biogas plant is modelled, a general matrix notation is used:

Maximize $\{Z = c'x\}$

Subject to: $Ax \leq b$

$x \geq 0$

Where:

x vector of activities

c vector of gross margins per unit of activity

A matrix of technical coefficients, and

b vector of available fixed inputs and institutionally set constraints

The objective function (first row) contains variables related to electricity and digestate sales and costs related to labour, maintenance, inputs (biomass) and transport (no storage assumed).

For example maintenance costs is part of the vector c. In the objective function in the vector x there is an activity specified as kWh production. Further the gross margin per unit of this activity is specified in vector c.

The set of constraints (second row) are related to technical processes of biogas production, electricity (and heat) generation, digestate processing, allocation of inputs (biomass), allocation of labour, policy constraints (such as the maximum uptake of nutrients) and digestate transporting to export regions.

For example, one constraint is about the availability of the digester. In matrix A, for this particular constraint technical coefficients determine how much of each input is allowed to be digested. And this should not exceed the maximum capacity of the digester, which is part of vector b.