UNIVERSITY OF TWENTE. SUBMITTED: 26-06-2013

THE SUCCESS FACTORS OF THE DEVELOPMENT OF BIOGAS WITHIN GERMANY - A CASE STUDY

BACHELOR THESIS

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I. Abstract

This thesis analyses the causes of the rapid development of the biogas sector within Germany. The aim behind this analysis is to be able to give, based on the development of the German Biogas sector, recommendations to other European Governments who wish to increase the production of electricity generated from biogas. In order to identify the causes, this thesis rests on two pillars; a theoretical part, in which it will be highlighted why Porter's Diamond is, for the purpose of this thesis the most applicable framework, and an empirical part in which, based on the Lower Saxon Biogas sector, different (possible) causes will be analyzed. This analysis rests thereby mainly on quantitative data, and gets backed up by interviews with experts of the Lower Saxon Biogas sector. The finding suggest that the artificially created demand on biogas, as well as the availability of maize and a short distance of biogas plant operators to supportive and related companies, can be considered as causes which explain the rapid development of the biogas sector within Germany.

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II. List of Abbreviations

BGBl:	Bundesgesetzblatt (Federal Law Gazette)
EEG	Erneuerbare Energien Gesetz (Renewable Energy Act)
EU:	European Union
Ha:	Hectare
IEA:	International Energy Agency
KW:	Kilowatt
KWK:	Kraft-Wärme Kopplung (Combined Heat Power)
LSU:	Life Stock Unit
MW:	Megawatt
NAWARO:	Nachwachsende Rohstoffe (Renewable Resources)
T:	Ton

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1. Introduction

Renewable energies matter. Taking into account, that according, to the International Energy Agency (IEA), the worldwide energy demand will until 2035 increase by more than 30% (IEA 2012), it becomes clear that the fostering of renewable energies is not only necessary in order to save Greenhouse Gas emissions, but also in order to guarantee, having the finite nature of fossil resources in mind, the supply of energy. Convinced by the importance of renewable energies, formulated the European Union within, for the European Union highly relevant strategy paper Europe 2020, the ambitious aim of having 20% of the energy consumed within the European Union by 2020, coming from renewable energies (European Commission, 2010). However, keeping the almost blackouts within Germany in the winter 2011 and 2012 in mind, which were, due to bad weather conditions, a result of the incapability of the Wind and Solar sector to produce enough energy, it becomes clear that besides these rather "climatic dependent" energy sources other, more manageable, renewable energy sources are needed. One of these more manageable renewable energy sources is Biogas. Due to the fact that biogas is mainly produced "*in biogas plants by the biological degradation of biomass – primarily agricultural substrate such as liquid or stable manure or energy crops (especially maize, but also rye, sugar beet, etc.), or from organic waste from rural districts, towns and villages, such as cutgrass, waste food and by-products of the food industry"* (Fachverband für Biogas, 2011, p. 6), biogas plant operators are, on a daily basis, able to adjust the supply of Biogas energy with the demand.

However, despite the overwhelming advantage of being a renewable resource capable of adjusting demand, by looking at the literature/statistics regarding the biogas production within Europe it becomes clear that in many member states of the European Union, the Biogas sector is not as developed as it could be the case (Trän, Seiffer, Müller-Langer, Plättner, & Vogel, 2007; AEBIOM, 2009; Holm-Nielsen, Seadi, Oleskowicz-Popielc, 2009; Cross Border Bioenergy, 2012; Eurobserver, 2012). Nevertheless, there are also countries within Europe where the Biogas sector is already fairly developed, for example Germany. Currently 15,1% of the electricity and 8,1% of the thermal energy (heat) produced from renewable energy within Germany, comes from Biogas (Deutsches Umweltbundesministerium, 2013). Focusing at the Electricity market in total Biogas is expected to contribute 3,73% of the electricity consumed in Germany in 2012 (Fachverband für Biogas, 2011). Even though this number seems to be relatively small, one has to keep in mind that due to the production of Biogas 6.5 million German households can be supplied with electricity (Fachverband für Biogas, 2011). What makes these numbers even more unique is the fact that the Biogas sector compared to Solar, Photovoltaic and Wind energy is a rather new sector. The rise and development of Biogas plants only started in 2000, before that Biogas hardly played any role. The statistics underline this, as in 1998 only 400 Biogas plants could be found in Germany (de Graaf, & Fendler, 2010). By 2011 the amount of Biogas plants had dramatically increased up to 7215 Biogas plants (Fachverband für Biogas, 2011). However how developed the German Biogas sector is, compared to other European countries, becomes clear by looking at the percentage of electricity generated from biogas in Germany. With 46% (Eurobserver, 2012) of the overall

energy generated from biogas within Europe, Germany takes a leading role among the member states of the EU regarding the production of biogas.

1.1 Research questions

Given this predominance of the German biogas sector within Europe it would be interesting to identify the causes which influenced the development of the German biogas sector. In order to be able to give recommendations to other member states, who wish to increase the production of electricity generated from biogas. Thus the two main aims of this thesis are:

(1) *Identifying the causes that influenced the development of the biogas sector within Germany*
(2) *Give recommendations to other European member states who wish to increase the production of electricity generated from biogas, based on the identified causes.*

However, before identifying the causes that influenced the development of the biogas sector within Germany, a general description of the development of the German Biogas sector is necessary. Therefore the first research question to be addressed is:

1. *How did the Biogas sector develop within Germany between 2000 and 2011?*

After having described the general development of the German Biogas sector attention can be drawn on the causes that explain the increase of the biogas production, thus the second research question to be answered is:

2. *What caused the increase of biogas production during the years 2000-2011 in Germany?*

Based on the findings of research question one and two, the third and last question below shall help to process the research findings into recommendations to other European member states, who wish to increase the production of electricity generated from biogas;

3. *Given the answers to research question one and two, what can be recommended to other European Governments who wish to increase the production of electricity generated from biogas?*

However, in the context of a bachelor thesis it is hardly possible to analyze all possible causes of an increased biogas production in a systematic and all-encompassing way. Therefore the focus of the research is narrowed: theoretically and empirically. The following theoretical chapter (chapter 2) will outline how the application of Porter's Diamond as theoretical framework narrows the theoretically perspective of this thesis. Within this theoretical chapter possible causes for the development of the German Biogas sector, as well as those indicators that shall help to measure these causes, will be introduced.

The usage of the Lower Saxon Biogas sector as representative example for the German Biogas sector, limits this thesis empirically. Thus after a brief description of the development of the German Biogas sector, (chapter 3.) the results of the analysis regarding possible causes which influenced the development of the biogas sector within Lower Saxony will be presented (chapter 4).

The last chapter of this thesis will give recommendations to other European Governments who wish to increase the production of electricity generated from biogas (chapter 5), based on the findings presented within chapter three and four.

1.2 Methodology

As said before, in order to identify the causes that explain the increase of the biogas production within Germany, the author will use the Lower Saxony Biogas sector as case study. In order to understand the reasons for, (1) choosing a case study as research strategy and (2) using Lower Saxony Biogas sector as representative example for the German Biogas sector, the first two parts of this paragraph are designed to (1) elaborate on the advantages of using a case study in this context and to (2) outline why the Lower Saxon biogas sector can be considered as a representative example for the German Biogas sector. The last part of this paragraph (3) is aimed to illustrate how the data was collected and analyzed.

1.2.1 Case study as research strategy

There are various reasons why conducting a case study is the best "*research strategy*" (Yin, 1994, p.13) in this context. First of all it has to be emphasized that the holistic approach of a case study (Yin, 1994) suits the purpose of this thesis best. As it will be outlined in the theoretical framework there are many factors which could have influenced the development of the biogas sector, making a holistic approach towards the development of the biogas sector essential. Secondly, case studies are according to Yin (1994) designated to answer *"how"* or *"why"* questions when the investigator has little or no control over the events which are to be analyzed. In order to understand the third and last reason for choosing a case study as research strategy, attention has to be drawn first to the definition of Gerring (2004, p. 342) who defines a case study "*as an intensive study of a single unit for the purpose of understanding a larger class of (similar) units".* Indeed, as it will be argued in the next part of this chapter, the Lower Saxon Biogas sector shall be used as representative for the German Biogas sector; thus, the findings of the Lower Saxon Biogas sector shall be *"generalized"* for the German Biogas sector.

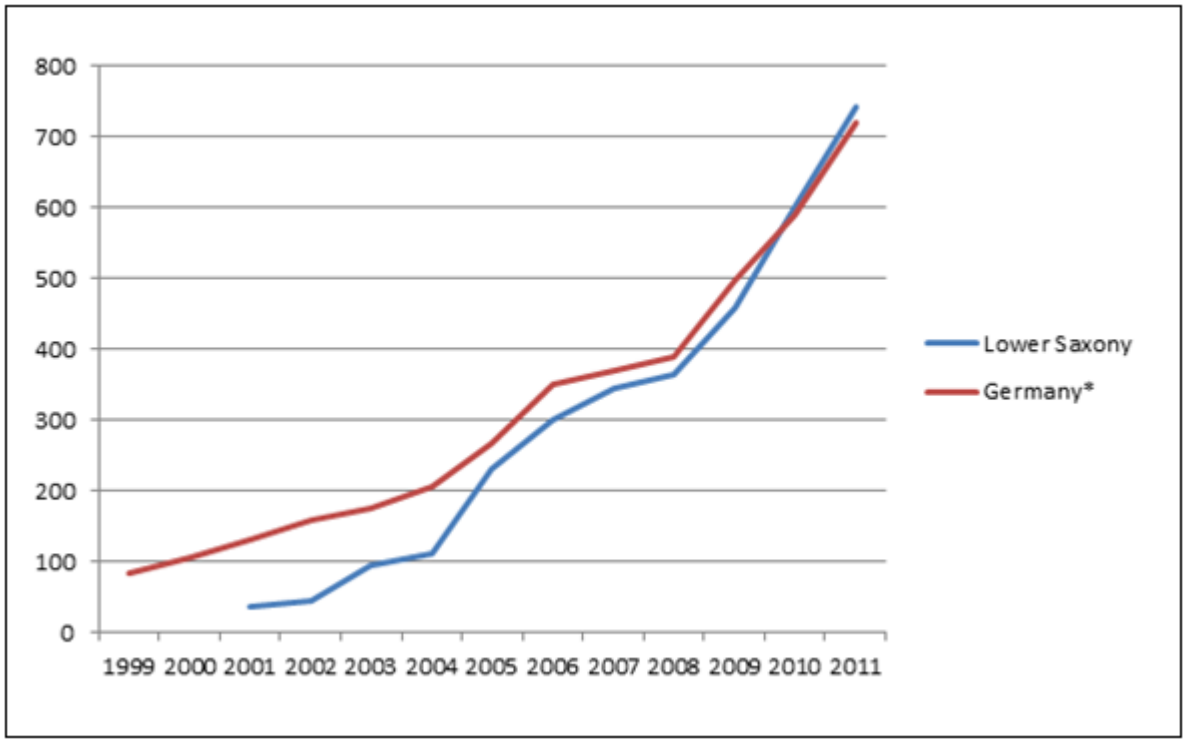
Thus, speaking with the words of Gerring (2004) the *population* will be the German Biogas sector, the *sample* will be the Lower Saxon Biogas sector and the units of analysis will be the different regions of Lower Saxony (below it will be argued how the different regions will be grouped). Given that there are four *"subunits"* (Yin, 1994, p. 41) which are to be analyzed as

units of analysis within this thesis, the design of this case study will be according to Yin (1994) an embedded single case design.

1.2.2 Lower Saxon Biogas sector as Case study

As said above the Lower Saxon Biogas sector shall be used as a representative example for the German Biogas sector. There are various reasons to do so. First of all the growth rate of operational biogas plants within Lower Saxony (similar to other states of Germany (Bundesländer)) almost follows the same trend as the growth rate of operational biogas plants within Germany: a notable increase in 2005 and 2009, combined with a moderate slow down within the growth rate of operational biogas plants in 2007 and 2008 (In the appendix, other graphs, showing the similar development of the amount of operational biogas plants within other Bundesländer, can be found)

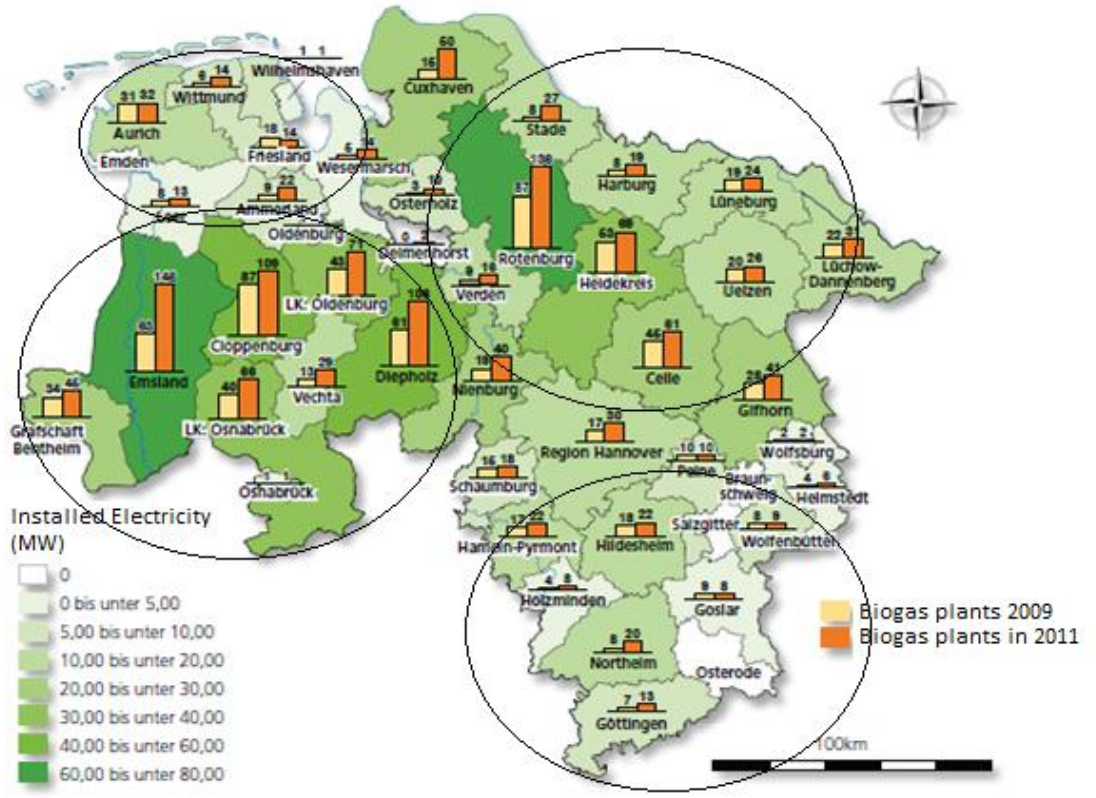
Figure 1. Amount of operational Biogas plants within Germany and Lower Saxony



* in order to illustrate the similar development in a most coherent way the amount of German Biogas plant got divided by ten
Source: Own calculation by the author based on data from: Niedersächsisches Ministerium für Ernährung, Landwirtschaft, Verbraucherschutz, und Landesentwicklung (2012); Fachverband Biogas (2011)

Secondly, as figure 2 points out, there is a great difference when it comes to the density of Biogas plants within the districts of Lower Saxony, therefore it must be possible to identify one, or possible more conditions outlined within the theoretical framework that do explain these differences.

Figure 2. Biogas plant density within Lower Saxony



Source: Niedersächsisches Ministerium für Ernährung, Landwirtschaft, Verbraucherschutz, und Landesentwicklung (2012).

By referring to the differences between the districts of Lower Saxony regarding the density of biogas plants it has to be mentioned that districts in particular areas of Lower Saxony seem to have more favorable conditions than districts in other areas of Lower Saxony. The conditions for the biogas production in the South, particularly in the south east, of Lower Saxony seem not to be very favorable, especially in districts like Osterode, Goslar and Göttingen. Similar to these districts, but slightly more productive seem to be the districts in the North-West such as Aurich, Wittmund, and Ammerland. The districts around Celle, Gifhorn and Uelzen are the average districts regarding the biogas production. The leading districts are most certainly those in the West, such as Emsland, Cloppenburg and Osnabrück. Having highlighted that the differences regarding the amount of produced biogas within Lower Saxony, can be categorized in regional differences (South-East; North-West; North-East, Central; West), it makes sense to further base the analysis on those regions instead of districts. In order to most accurately allocate all the districts of Lower Saxony to a region, this thesis will make use of the results of the work done by Höher, Theuvsen, Plumeyer, and Emman (2011). The final list, which includes all districts and their allocation within a region, can be found within the appendix. By referring to the work of Höher et al. (2011) it has to be mentioned that Höher et al. (2011) named these different regions according to the dominating kind of agriculture within those regions. Given that the dominating kind of agriculture within a region can give already valuable inferences regarding the availability of resources such as maize or liquid manure within a region, this thesis will continue with the names proposed by Höher et al.

(2011). Thus from now on instead of referring to the Western; North-Western; Central and South-Eastern regions the author of this thesis will refer to the Veredlungsregion (refinery region); Futterbauregion (Fodder cultivation region); Heide-Beregnungsstandorte (heather-sprinkling locations) and Ackerbauregion (cropland region). The table below, which shows the average amount of Biogas plants as well as the average amount of electricity generated from biogas per districts within the different regions confirms the observation explained above. Highlighting the big discrepancies between the cropland region (8 biogas plants per district on average; 5MW installed electricity per district on average) and the refinery region (70 biogas plant per district on average, 35,56MW installed electricity per district on average).

Table 1. ø amount of Biogas Plants and their amount of installed capacity per district within the different Regions of Lower Saxony

	Lower Saxony	Cropland region	Fodder cultivation region	Heather-sprinkling-locations	Refinery region
ø amount of Biogas Plants per district	32	8	18	41	70
ø amount of installed capacity in MW per district	17,56	5	10,91	21,67	35,56

Source: Creation of the author based on the data from: Niedersächsiches Ministerium für Ernährung, Landwirtschaft, Verbraucherschutz, und Landesentwicklung (2012)

1.2.3 Data Collection and Analysis

In order to guarantee a high level of construct validity within this thesis, various data sources were used. According to Yin (1994) who labels this usage of different data sources within a case study as triangulation of data, this method will lead to the findings and conclusions which are *"much more convincing and accurate"* (1994, p. 92).

These different data sources cover legal documents, information sheets, designed by professional associations, statistics released by the Lower Saxon ministry of Agriculture, literature and expert interviews. The legal documents encompassed the development of the renewable energy law, and were found within the Bundesgesetzblatt (Federal Law Gazette). The Information sheets, designed by the professional associations, were used in order to gain a sophisticated overview regarding the numbers related to biogas. These numbers were the amount of produced biogas and the amount of operational biogas plants, found from the websites of the professional associations. The statistics released by the Lower Saxon ministry of Agriculture were necessary to identify the differences in agricultural structure between the regions of Lower Saxony. These were found from the website of the Lower Saxon ministry of

Agriculture. The literature used within this text was mainly used in order to develop *"theoretical propositions that guide the data collection and analysis"* (Yin,1994, p. 13). Therefore, due to the fact that biogas is a relatively new topic compared to other renewable energy sources and has not yet played a crucial role within the international scientific world, attention was mainly drawn towards German authors. In order to ensure a high level of reliability of these data sets, several interviews with recognized experts in the field of biogas have been conducted. The Interviews have been executed by telephone and took between 15 to 30 minutes. These interviews were audio taped with the permission of the interviewee. An interview protocol can be found within the appendix.

Table 2 presents a general overview of the data which was used to answer the research questions found attached to the operationalization in chapter 2.3.

2. Theoretical Framework

The aim of this theoretical chapter is twofold; first of all this part shall convince the reader that Porters Diamond is, for the purpose of this thesis, the most suitable theoretical framework; Secondly it shall provide the foundation for the further analysis by applying Porters Diamond to the development of the biogas sector. In order to achieve this aim this part is built up as follows; first of all some theories on regional development will be introduced, which shall highlight the different approaches towards regional development. The second part is going to build up on the first part by explaining the most suitable theory (Porter's Diamond), for the purpose of this thesis, in more detail. The third and last part of this chapter will deal with the operationalization of the abstract concepts of Porters Diamond in measurable indicators, which can be used for the further analysis of this thesis.

2.1 Theories on regional development

Neo-classical approach

The first theory to be introduced is the neo-classical approach towards regional development, which has its roots within the *"tradition of the classical economics of David Ricardo, John Stuart Mill and Adam Smith*" (Pike, Rodriguez-Pose.,& Tomaney, 2006, p.62) According to this theory the regional output growth depends on three factors; (1) Growth of capital stock; (2) Growth of labor force; and (3) technical progress (Pike 2006). In order to guarantee that this "*free market approach*" (Pike, et al., 2006, p. 68) works as efficiently as possible the government shall fulfill only two tasks; (1) Deregulate the regional labor market and (2) provide tax incentives. The main strength of this theory is thereby that it highlights that regional development can be influenced by various factors. However, besides the rather ideologically based criticism such as that formulated by Howes and Markusen (1993, p.35) *("there is some danger that the unfettered pursuit of free trade will actually depress wages and employment and lower world living standard"*), this neo-classical approach is often criticized for been too static and neglecting the importance of the interplay between various government and non-governmental organizations (Armstrong and Taylor 2000).

Triple Helix

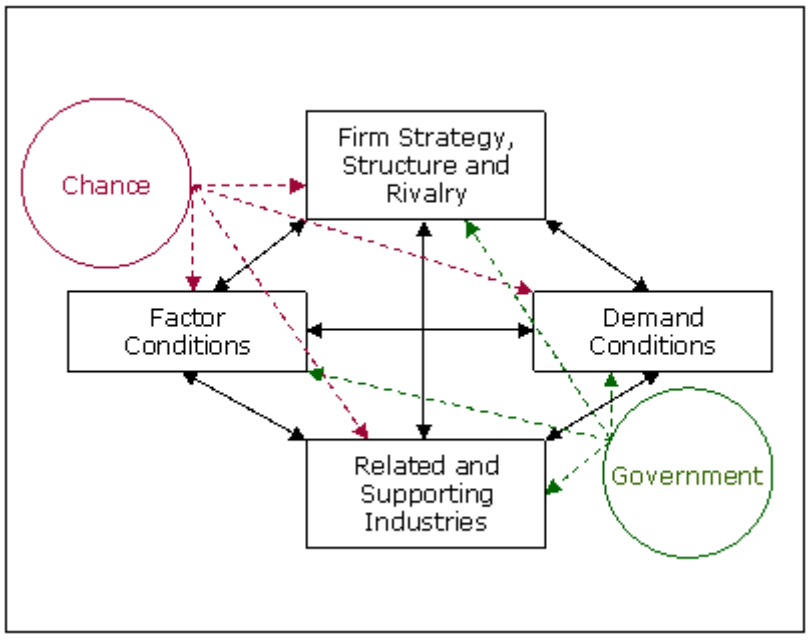
Having outlined one of the main weaknesses of the neo-classical approach regarding regional development, attention shall be drawn towards a theory that recognizes the interplay of various governmental and non-governmental organizations. One of the most well-known theories in this context is the triple helix approach formulated by Etzkowitz (2008). For Etzkowitz (2008) the key for innovation and growth within regions is the interaction among

university, industry and government. Therefore each of these three actors has to fulfill different tasks in order to facilitate the most effective as possible interaction between each other. Universities should transform themselves into so called *"Entrepreneurial universities"* which shall serve as *"recognized sources of technology as well as of human resources and knowledge"* (Etzkowitz, 2008, p. 29). Companies should "*pursue their growth strategies based on academic innovation and incubation"* (Etzkowitz, 2008, p. 44). The role of the government is twofold, on the one hand it shall implement effective innovation fostering policies; but, on the other hand it shall not interfere too much within the innovation building processes (Etzkowitz, 2008). However, in order to find the causes of the raise of the biogas sector, focusing only on the needed interplay of the government, the universities and the companies, would not be beneficial, given that it would be a too narrowed approach, leaving important factors such as demand conditions and the availability of resources out.

Porter's Diamond

A model that includes factors like demand conditions and the availability of resources, but, also recognizes the importance of having cooperating governmental as well as non-governmental organizations is Porter's Diamond. With the development of this model, Porter (1990) aimed to provide a theoretical explanation of a competitive advantage of countries or sectors within countries. As outlined in Figure 3 below, Porter (1990) separates the causes for a competitive advantage into four mutually beneficial attributes, (1) Firm Strategy, Structure and (Domestic) Rivalry; (2) Factor Conditions; (3) Related and Supported Industries (4) Demand. These four, interdependent attributes, get additionally influenced by two other factors, (1) Chance and (2) Government. In the following part of this chapter each of the attributes as well as the two factors will be shortly addressed in order to understand the theoretical framework, and the importance of using it in this context, more easily.

Figure 3. Porter's Diamond Model



Source: Porter (1990)

2.2 Porter's Diamond in more detail

Demand Conditions

The attribute "demand conditions" puts according to Porter (1990, p. 82) emphasis on the importance of a home demand that gives a *clearer or earlier picture of emerging buyer needs* than the international demand. Thus the home demand might lead according to Porter (1990, p. 82) to an *"early warning indicator* for the global demand. Crucial for the development of such an early warning indicator is that buyers of such a product are the world's most "*sophisticated and demanding buyers"* (Porter, 1990, p. 82). These kinds of buyers have according to Porter (1990, p. 82) *the possibility to pressure companies to meet high standards.* This makes it a necessity for companies to further develop, with the help of innovation and upgrades, a better product. Besides the anticipation of needs by local buyers, it might also be the case that local buyers shape a trend with their consumption of a special product which will spill over to other countries. An example used by Porter (1990) is the Danish environmentalism, which has according to Porter (1990) led to the success of the windmill sector within Denmark.

Factor Conditions

By starting the description of the attribute "*factor conditions*" one has to admit that Porter (1990, p. 79) neglects the importance of factors such as labor, land, natural resources, capital and infrastructure, which do play a crucial role in the standard economic theory. According to Porter (1990) they do not necessarily constitute an advantage for the competitiveness of a nation, but might even lead to a disadvantage of the nation's competitiveness. The reason for this line of argumentation is that Porter's (1990, p. 79) beliefs that such basic resources such as labor, land and natural resources do not "*constitute an advantage in knowledge based industries*", due to the fact that "*Companies can access them easily through a global strategy or circumvent them through technology"* (Porter, 1990, p. 79). Instead according to Porter (1990, p. 79) a factor must be highly specialized to an industry's particular needs. Thus in order to achieve a competitive advantage a nation needs to have "world class institutions that first create specialized factors and then continually work to upgrade them" (Porter 1990, p. 79). An example that illustrates the factor conditions quite nicely is the export of insulin that is fabricated in Denmark. For Porter (1990) this high export rate of Insulin produced in Denmark is partly a result of the existence of two hospitals which specialized on research and development regarding diabetes. Porter (1990) explicitly warns against the belief that having a huge stock of resource will automatically lead to good factor conditions. Instead he (1990, p. 79) is able to show on the example of Japan that having no resources, can under the right conditions lead to a competitive advantage, given that countries/industries/companies *"must innovate and upgrade to compete"*.

Related and Supportive industry

The next attribute "related and supported industry" is mainly a key attribute, because of the importance of a close working relationship between companies and the trust which results from this close working relationship. Porter (1990, p. 83) argues in this context that *short lines of communication, quick and constant flows of information and an ongoing exchange of ideas and innovation* can be seen as a major competitive advantage of a country/industry/ companies. This leads automatically to a quicker access of machinery and components.

Firm Strategy, Structure and domestic rivalry

The attribute Firm Strategy, Structure and (domestic) Rivalry is probably the vaguest of all four attributes, given that it focusses on three different aspects; the strategy, the structure and the rivalry of firms within a country. According to Porter (1990) all three sub-attributes are important and play a key role in determining the competitiveness of a nation/company/ industry. Therefore Porter (1990, p. 83) notes that no *"managerial system is universally appropriate";* thus, the structure of the firms vary depending on the culture/customs from country to country. An interesting point to mention in this context is that Porter (1990, p. 83) sees a direct connection between the management structure within Germany and the success of *"the technical or engineering- oriented industries – optics, chemicals, complicated machinery – where complex products demand precision manufacturing, a careful development process and after sales service."* Culture again plays a fundamental role within the next sub-attribute, strategy. Porter (1990) is able to outline that the strategy of companies varies similarly to the structure of the management from country to country. As an indicator that explains the different strategies Porter (1990) uses the different national capital markets and the compensation practices for managers. According to Porter (1990), based on this practice, one can conclude that in some countries one is more likely to find a company based on the idea of long term strategy and focuses its strategy on mature industries. However, in other countries the opposite might be the case. The result is that due to short term interests new industries, which have more potential to generate short term profits, are more likely to be found. (Domestic) rivalry the last sub-attribute is following Porters (1990) line of argumentation, the most important point in his Diamond. The reason why Porter (1990) labels (domestic) rivalry as the most important aspect within his Diamond is because Porter beliefs that only if there is a domestic rivalry will companies put emphasis on the fostering of innovation and upgrading, in order to be able to compete with their rivals. Quoting Porter (1990, p. 85) *"the more localized the rivalry, the more intense. And the more intense, the better".*

Government and chance

After having explained the four different attributes that are used in Porters Diamond it is now time to focus on two factors which can, under certain circumstances, influence all four attributes, (1) Government and (2) Chance. The government shall thereby according to Porter

(1990, p. 87) act as "*catalyst and challenger"*. For Porter (1990, p. 87) this means that the government shall create an *"environment in which companies can gain a competitive advantage"* Thus the government shall play an "*indirect role"* (Porter, 1990, p. 87) in the process of building a national competitive advantage. Japan is an example which comes closest to the best government outlined by Porter (1990). Following Porters (1990, p. 87) line of reasoning the Japanese government played a major role in *stimulating early demand for advanced products.* As a consequence companies were obliged to innovate and upgrade their products. The other factor, chance, can have a huge impact on the diamond model as well. Porter (1990) argues that due to environmental disasters, wars and other unforeseeable events nations/industries/companies may gain, or lose a competitive advantage.

2.3 Operationalization of Porter's Diamond

Demand Conditions

Generally speaking the demand of a certain good, depends on the willingness and the ability of the consumers to purchase a certain good (Mankiw and Taylor, 2006). However, Mankiw and Taylor (2006) are able to outline that, due to government incentives, the demand of a certain good can get heavily influenced, and thus does not depend solely anymore on the willingness and the ability of the consumers to purchase a certain good. With respect to biogas, scientists (Hundt, 2010; de Graaf, & Fendler, 2010; Poeschl, Ward, & Owende, 2010; Delzeit, Holm-Müller, & Wolfgang Britz 2011; Klagge, & Brocke, 2012; C. Lacü, personal communication, June 10, 2013; G., C. Höher, personal communication, June 13, 2013; M. Kralemann, personal communication, June 17, 2013) agree that with the EEG, an artificial inexhaustible demand for biogas was created by the German government, that had no relationship anymore with the willingness and the ability of consumers to purchase biogas. Given that with the help of the EEG a new, artificially, demand got created it makes sense to base the further analysis regarding demand conditions on the development of the EEG. In order to test the influence of the EEG on the development of the biogas sector within Germany the history of the EEG and its influence on the amount of biogas plants will be considered. An increase within the amounts of biogas plants which happens to occur right after amendments made on the EEG would thereby indicate the influence of the EEG on the biogas sector.

Factor conditions

Even though Porter (1990) neglects the importance of natural resources, land and infrastructure to a certain degree, in the case of the Biogas sector one can expect that these factors play an important role. Especially the availability of resources needed to operate the biogas plants are expected to be of great relevance. Following the calculation of the Fachagenut für Erneuerbare Energien (2013) in order to be able to operate a 350 kwh biogas plant 5500 t of maize, 3000 t of liquid manure and 1000 t of cereals are needed per year. By focusing on these numbers, tt has to be mentioned, that these numbers, show just one possibility of establishing a resource mix for a biogas plant, instead of using 1000 t cereals

biogas plant operators could also use more liquid manure or more maize. However, it is highly unlikely that cereals or liquid manure will have a higher share within this resource mix than maize. Experts (Hunt, 2010; Lacü, personal communication, June 10, 2013;G., C. Höher, personal communication, June 13, 2013;) agree in this context that among those resources maize is most certainly the most often used resource and has important advantages compared too the other resources.

According to Lacü, (personal communication, June 10, 2013) there are two reasons that explain why maize is so heavily used for the production of biogas. The first reason is that maize has the highest methane earning per hectare among those resources which could be used for the production of biogas (Figure 1 within the appendix confirms this argument empirically).Therefore, given that a higher methane earning per hectare means more generated electricity per hectare, it makes, from an economic perspective more sense for agriculturists to use maize than other resources. The second advantage of maize, according to Lacü (Lacü, personal communication, June 10, 2013) is, that agriculturists are familiar with the cultivation of maize and thus do neither need to gain new knowledge regarding the cultivation practices of a new type of plant, nor do they need to invest in new equipment (harvesting machinery etc.).

By taking the results of Höher et al. (2011) who are able to outline that long distance transport of maize, are neither favorable for the maize, nor is it economically favorable for the biogas plant operator, into account, it becomes obvious that the availability of maize within **a close proximity**, is of great importance for the Biogas plant operators, and will, to a certain extent, help to explain why there are differences within Germany (Lower Saxony) regarding the density of biogas plants.

Thus it is expected that those regions with a higher maize density have a clear competitive advantage compared to other regions and thus do have a higher density of operational biogas plants. After having determined the differences between the regions, regarding the maize density, attention shall be drawn towards possible factors that explain these data.

Supportive and related industry

Within the biogas industry trust among the different actors is of great relevance. According to Höher (2011) 80% of the biogas plants are owned by agriculturists, who have fundamental knowledge when it comes to cultivating agricultural products but lack knowledge when it comes to optimizing the chemical and biological processes taking place within the biogas plant. Therefore, short lines of communications and relationships build on trusts between the biogas plant operators and the biogas service companies are of great importance (C. Lacü, personal communication, June 10, 2013; G., C. Höher, personal communication, June 13, 2013; M. Kralemann, personal communication, June 17, 2013). Based on this argumentation, it is expected that related and supported industry will play an important factor in explaining the success of the German Biogas sector. In order to test this, those companies which are members of the German Professional association for biogas (Fachverband Biogas e.V.) will be listed on a map of Lower Saxony. Ideally there would be a high density of those companies

within regions where there is also a high density of biogas plants. In addition to these companies direct connected to the biogas sector the subsidiaries of the Agravis technique GmbH, which is according to Bronsema and Theuvsen (2010) the marker leader within the agricultural supplying and maintaining market, within Lower Saxony, will be mapped.

Firm Strategy, Structure and domestic rivalry

By drawing the connection between the rise of the biogas sector and this attribute, one has to admit that structure and strategy are expected to play only a marginal role in explaining the rise of the biogas sector. Of course, Porter (1990) sees a connection between the success of the German technical or engineering industries and the German management structure. As discussed above the majority of biogas plants are owned by agriculturists, who in most of the cases operate the biogas plant by themselves. Therefore, it can be expected that finding complex management structures and strategies, which explain a competitive advantage, will be impossible.

In contrast, by looking at the process of production of Biogas, which requires huge amounts of biomass and/or liquid manure, it is likely that an increased (local) rivalry between the biogas plant operators, and hence, a cause for the competitive advantage, can be observed. In order to measure an (increasing) rivalry between the Biogas plant operators, the price development for rented (agriculture) land shall be analyzed. A dramatic increase in the price of (agriculture) land, especially within those regions where biogas plays an important role, would thereby indicate an increasing rivalry.

A second indicator to be measured is the amount of shutdowns of agricultural holdings. There is no doubt that within those regions with the highest shutdown rate the rivalry, among agriculturists, is the most intensive and following the line of argumentation by Porter(1990) would mean that those regions have a competitive advantage. That the shutdown rate of agricultural holdings within Lower Saxony is an important factor get underlined by focusing on the work of Höher et al. (2011) who highlight, in their paper, that there is a huge cut-throat competition among agricultural holdings within Lower Saxony. During the peak period between 2005 to 2007 this results in an average shutdown of 4,4 agricultural holdings per day (Höher et al., 2011).

Below in table 2 an overview of the different indicators to be analyzed, based on Porter’s Diamond, can be found.

Table 2. Overview of the different attributes/indicators that will be analyzed

Attribute	**Indicator**	**Main Data source**	**Influential if…**
Demand Conditions	Development of the EEG	1. BGBl 2. Fachagentur für Biogas e.V.	A significant increase in the growth rate of biogas plants is observed after the amendments made on the EEG
Factor Conditions	Availability of Maize	1. Höher (2012)	More Maize is cultivated within those regions where biogas is more prevalent than in those regions where biogas plays only a marginal role
Related and Supported Industry	Location of Related and Supported Industry	1. Fachverband für Biogas e.V. 2. Agravis	A higher amount of related and supportive biogas companies can be found within those regions where biogas is more prevalent than in those regions where biogas plays only a marginal role
Firm Strategy, Structure and domestic rivalry	1.Price development for rented Land 2. Shut downs of agricultural holdings	1. Lower Saxon Statistical office	The price for rented agricultural land increased more within those regions where biogas is more prevalent than in those regions where biogas plays only a marginal role The shutdown rate of agricultural holdings is higher within those regions where biogas is more prevalent than in those regions where biogas plays only a marginal role

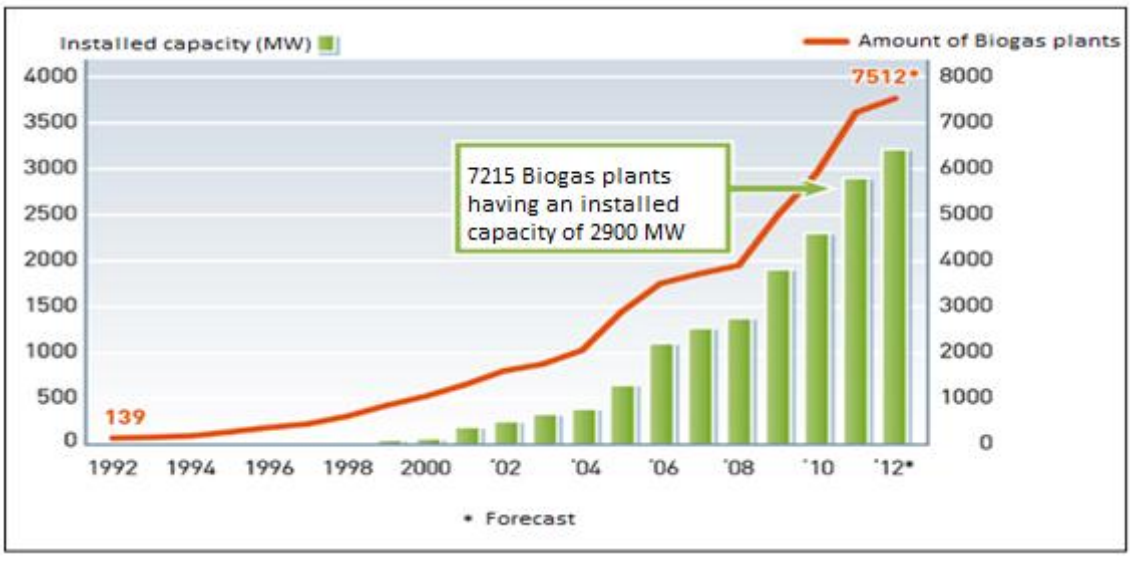
Source: Creation of the author

3. General Development of the German Biogas sector

As discussed in the first chapter of this thesis, the first research question to be addressed is: *How did the Biogas sector develop within Germany between 2000 and 2011*. In order to answer this research question, this chapter will describe figure 4 below which shows the amount of biogas plants, and their installed capacity within Germany.

By looking at figure 4, *Biogas plants within Germany between 1992 to 2012* one can identify four interesting patterns. The first pattern to be mentioned is, that the amount of operational Biogas plants within Germany, on an annual basis, always grew during the listed period. Secondly, by looking at the year of 2000, one has to admit that this year does not mark, with regard to the amount of operational biogas plants within Germany, any special point of departure. This becomes clear by looking at the growth rate of operational biogas plants within Germany in 1999 and 2001 which are as similar as possible to the growth rate of operational biogas plants within the year of 2000. The third pattern to be mentioned is the notable increase within the growth rate of operational biogas plants within Germany in 2005, 2006, 2009, and 2010. As it will be outlined within the next chapter of this thesis, evidence can be found, that this increase was a direct result of the amendments made by the German government on the EEG (Hundt, 2010; de Graaf, & Fendler, 2010; Poeschl, Ward, & Owende, 2010; Delzeit, Holm-Müller, & Wolfgang Britz 2011; Klagge, & Brocke, 2012; C. Lacü, personal communication, June 10, 2013; G., C. Höher, personal communication, June 13, 2013; M. Kralemann, personal communication, June 17, 2013). The last pattern to be mentioned in this context is; the moderate slow down within the growth rate of operational biogas plants within 2007 and 2008. Scientists (de Graaf, & Fendler, 2010; Delzeit, Holm-Müller, & Wolfgang Britz 2011) agree that, the main reasons for this moderate slowdown of the growth rate, was the increased maize price.

Figure 4. Development of Biogas within Germany



Source: Agentur für Erneuerbare Energien (2013)

Thus based on these findings one can conclude that the German Biogas sector, between 2000 and 2011, grew in considerable short time. Another notable observation is the influence of external events on the development of the biogas sector, such as the increase of maize prices or the amendments made by the German government on the EEG

4. Results

After having discussed the general development of the German Biogas sector, attention shall now be drawn on the analysis of the possible causes that could have influenced/stimulated this development. Similar to the structure of the theoretical chapter, first of all the demand conditions will be discussed, followed by factor conditions, supported and related industry and rivalry.

4.1 Demand Conditions

Given that, as said in the theoretical chapter, the EEG helped to create an artificial demand for biogas, the analysis of the development of the EEG is of great importance in this context. The history of the creation of the artificial demand for Biogas by the German government, with the help of the EEG, began in 1990, when the legal predecessor of the EEG, the electricity feed-in law (Stromeinsparungsgesetz) was created. This law obliged, for the first time, grid operators to feed-in electricity produced from renewable energy sources such as biogas (BGBl, 1990). Important to mention in this context is that the grid operator had to pay the biogas plant operator 80% of the price which they received from the end-user (BGBl, 1990). This changed in the year 2000 when the renewable energy act was introduced and with it some interesting changes for biogas plant operators. The first one to mention is that since 2000 biogas plant operators receive a fixed price, per kilowatt hour, for a time of 20 years (BGBl, 2000). Secondly, the German Legislator introduced a price scheme for electricity produced by biogas plants which was dictated by the capacity of the biogas plant. Biogas plants with a capacity to produce electricity up to 500 kw per hour received 10 Cents per kilowatt hour; biogas plants having the capacity to produce up to 5 megawatt per hour received 9 Cents per produced kilowatt hour and biogas plants which have the capacity to produce more than 5 megawatt per hour received 8,5 Cents per produced kilowatt hour (BGBl, 2000). However, as figure 4 shows, despite the fact that biogas plant operators had for the first time the guarantee to receive a fixed price over the following 20 years, this change in legislation, did not lead to a rapid increase in the construction of biogas plants.

This changed in 2004 with the amendments made to EEG. The most important modification in this context was the establishment of the so called NAWARO Bonus (Nachwachsende Rohstoff Bonus, in English: renewable resources) (De Graaf and Fendler, 2010). This modification guaranteed biogas plant operators which operate their biogas plant solely with renewable resources a bonus of 6 cent per produced kilowatt hour (BGBl 2004). In addition biogas plant operators have since 2004 the possibility to receive the so called kwk bonus (Kraft wärme Kopplung, in Eglish: combined heat and power). This kwk bonus (2 cents per kilowatt hour), is to be received if biogas plant operators are able to use the heat, which is generated during the electricity winning processes, in an efficient way (BGBl, 2004). Another two cents bonus is paid if fuel cells, gas turbines, steam engines, organic Rankine cycles, multi-fuel facilities, or Stirling engines are used to generate electricity (BGBl, 2004). In addition to the extra bonuses mentioned above the renewable energy act of 2004 introduced a

new general price scheme. This is similar to the one of 2000, except that a difference is made between biogas plants which are capable of producing electricity up to 180 kilowatt per hour and biogas plants which are able to produce electricity up to 500 kilowatt per hour (BGBl, 2004). Table 3 shows the different price schemes, including possible bonuses outlined above.

Table 3. Prices in Cents per KW/hour for produced electricity, generated by biogas plants, after 2004

Max. Capacity to produce	Basic price (price before 2004)	Renewable Energy Bonus	Combined heat and Power Bonus	Gas turbines etc.	Possible total price
150 kW per hour	11,5 (10)	6	2	2	21,5
500 kW per hour	9,9 (10)	6	2	2	19,9
5 MW per hour	8,9 (9)	4	2	2	16,9
20 MW per hour	8,4 (8,5)	0	2	0	10,4

Source: Own Creation of the author, based on the Data from: BGBl (2000) and BGBl (2004)

By looking at the table above it becomes clear that biogas plant operators had the chance to receive almost twice as much as before the amendments of 2004. According to Graaf and Fendler (2010, p.13) this resulted in an extraordinary *"market explosion",* with almost four times the amount of produced electricity in 2006 compared to 2004.

Similar to the amendments made on the renewable energy act in 2004, came the amendments, made on the renewable energy act in 2008, with some, for biogas plant operators, lucrative modifications. Besides an increase of the bonus for combined head and power, and technology, the renewable energy act of 2008 encouraged biogas plant operator to make more use of liquid manure by introducing a bonus for biogas plants which have a lower capacity than 500 kW per hour (150 kW per hour = 4 cent; 500 kW per hour 1 cent) (BGBl, 2008). This bonus is paid if biogas plant operators are able to run their biogas plants with 30% of the total used biomass, coming from liquid manure (BGBl, 2008). Additionally a bonus for landscape conservancy was introduced, granting biogas plants with a maximum capacity of 500 kW per hour a bonus of 2 cents per kWh if an environmental auditor can approve that mainly plants or parts of plants are used for generating the electricity which accumulate as part of landscape management (BGBl 2008).

Table 4. Prices in Cents per KW/hour for produced electricity, generated by biogas plants, after 2008

Max. Capacity to produce	Basic price (price before 2009)	Renewable Energy Bonus	Combined heat and Power Bonus	Gas turbines etc. Bonus	Liquid Manure Bonus	Landscape conservancy bonus	Possible total price (price before 2009)
150 kW per hour	11,67 (11,5)	6	3	3	4	2	29,67 (21,5)
500 kW per hour	9, 18 (9,9)	6	3	3	1	2	24,18 (19,9)
5 MW per hour	8,9	4	3	3	0	0	18,9 (16,9)
20 MW per hour	8,4	0	3	0	0	0	11,4 (10,4)

Source: Own creation of the author based on the data from: BGBl (2004) and BGBl (2008)

By looking at the increase of the total possible price for small (150kW/h) and medium (500 kW/h) biogas plants one has to agree with Gruber (2009), who found out in his work, that mainly small and medium sized biogas plant operators benefited from the amendments made by the German legislator in 2008.

Thus as said within the theoretical chapter, the demand conditions, or to say it differently the artificially created demand by the German government can be considered as influential on the development of the biogas sector within Lower Saxony, if a significant increase in the growth rate of biogas plants after the amendments made on the EEG can be observed. As outlined above, this is clearly the case, confirming a causal relationship between the artificially created demand and the development of the biogas sector.

4.2 Factor Conditions

After having shown the impact of the artificially created demand on the development of the biogas sector attention shall be drawn on the question whether the availability of maize does help to explain the regional differences within Lower Saxony regarding the biogas production. Thereby, table five "*maize density within the different regions of Lower Saxony*" below is of great help. It represents the share of maize within lower Saxony's districts in relation to the overall agricultural usable land. Similar to the table regarding the density of biogas plants one can observe great differences between regions when it comes to the production of maize.

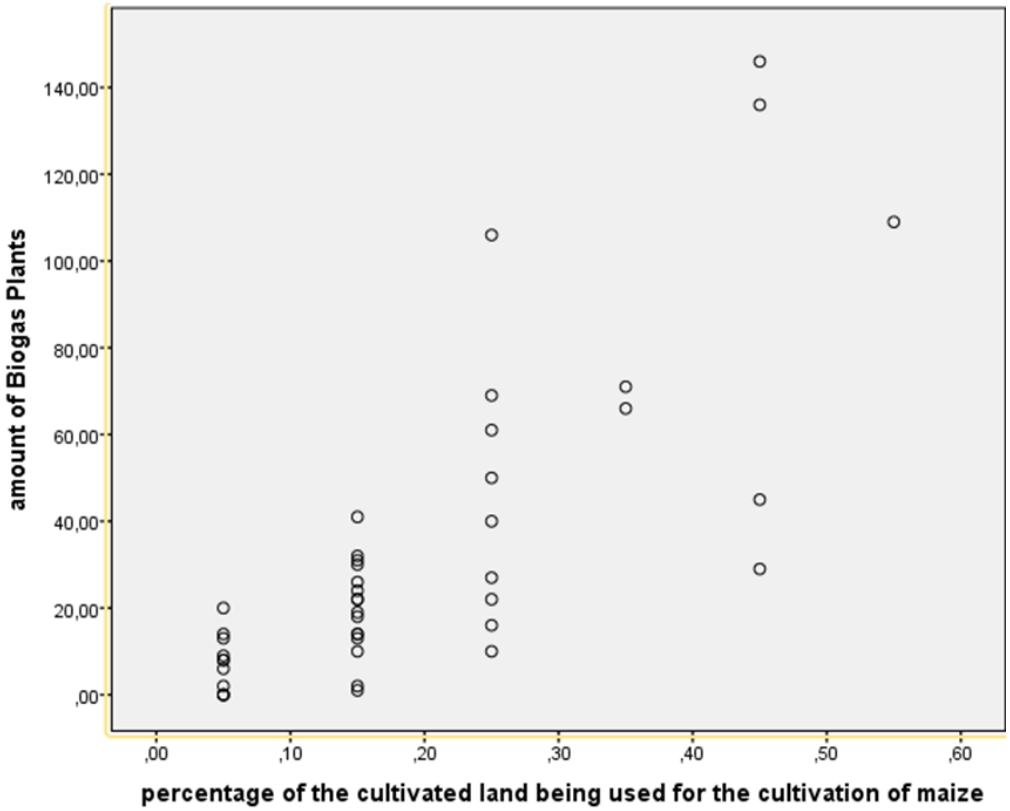
Table 5. Maize density within the different regions of Lower Saxony

	Lower Saxony	Cropland region	Fodder cultivation region	Heather-sprinkling-region	Refinery region
ø amount of Biogas Plants per district	32	8	18	41	70
Ø percentage of the cultivated land being used for the cultivation of maize	18,16	5,9	17,72	19,17	37,22

Source: Calculation of the author based on the data from: Niedersächsiches Ministerium für Ernährung, Landwirtschaft, Verbraucherschutz, und Landesentwicklung (2012) and Höher (2012)

The main conclusion that can be drawn from this table is that an increase in biogas-plants is most likely to coincide with an increase in percentage of the cultivated land being used for the cultivation of maize. The relationship is especially observable if one looks at the difference between the Cropland region and the refinery region. This tendency is even more obvious in figure 5, where all the different districts with regard to their amount of biogas plants and their percentage of the cultivated land being used for the cultivation of maize are imaged.

Figure 5. Relationship between the Maize density and the amount of Biogas plants within the districts of Lower Saxony



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Source: Calculation of the author based on the data from: Niedersächsiches Ministerium für Ernährung, Landwirtschaft, Verbraucherschutz, und Landesentwicklung (2012) and Höher (2012)

Another notable observation is that the difference regarding the maize production between the fodder cultivation region (17,72) and the heather-sprinkling region (19,17%) is not as big as expected. In order to be able to further elaborate on the reasons for these differences three other sets of data are needed to be introduced. First of all, according to Seide (2013), who is the president of the German Biogas association, one reason to explain the difference between the regions regarding the maize production, is that due to more favorable soil conditions it is more economical for agriculturists in the cropland region to cultivate other more valuable crops than maize, such as sugar beans and cereals. In order to underline this argument empirically, the German system of giving points to the soil needs to be introduced. This system is based on the idea that the soil can be ranked on a scale between 7 points (worst soil) and 100 (best soil) depending on some factors such as climatic conditions, existing nutrients and water holding capacity (Ratzke, & Mohr, 2003). Thus a high score of the cropland region regarding the soil would be the first step to empirically confirm the argument brought forward by Seide (2013). Indeed by looking at the numbers presented in table 6, one can conclude that the soil conditions within the cropland region (62) are much better than in the refinery region (35).

Secondly, in order to see whether it would be economically more favorable to grow cereals within those regions with a high score on the soil ranking, the earnings per hectare of cereals within the cropland region **must** be higher than in the refinery region. Again the numbers confirm the argument, showing a much higher average earning per hectare in t within the Cropland Region (7,5) than in the refinery region (5,9). Thus based on these statistics the argument by Seide (2013), that the production of maize, and hence the presence of Biogas plants, heavily depends on the soil structure, and connected with that on the opportunity of agriculturists to cultivate other, more valuable crops, is confirmed.

Table 6. Maize density in Lower Saxony in relation to the average soil points and earnings of cereals per hectare in t.

	Lower Saxony	Cropland region	Fodder cultivation region	Heather-sprinkling-region	Refinery region
ø amount of Biogas Plants per district	23	8	18	41	70
Ø percentage of the cultivated land being used for the cultivation of maize	18,16	5,9	17,72	19,17	27,22
Ø soil points within the regions	47	62	46	42	35
Ø earnings of cereals within the regions per hectare in t	6,7	7,5	6,6	6,5	5,9

Sources: Calculation of the author based on the data from: Niedersächsiches Ministerium für Ernährung, Landwirtschaft, Verbraucherschutz, und Landesentwicklung (2012) ,Höher (2012), Landesbetrieb für Statistik und Kommunikationstechnologie Niedersachsen (2011), Hiete (2009)

Besides the soil structure, and the connected opportunities for agriculturists to cultivate other crops, another factor that explains these differences regarding the production of maize is the so called refinery density (Veredlungsdichte). This refinery density resamples the quantity of

livestock, but also the size of the livestock. In order to categorize the different livestock in a more accurate way, the refinery density is often expressed with the help of the so called life stock unit (LSU) system. This system is based on the idea that each sort of livestock can be categorized on the basis of how much feed it requires. Thereby is "*the reference unit used for the calculation of livestock units (=1 LSU) the grazing equivalent of one adult dairy cow producing 3,000 kg of milk annually, without additional concentrated foodstuffs*" (EUROSTAT, 2013). In the appendix a table can be found showing the different sort of livestock and their score on the LSU system. Given that maize is an important part of the fodder for many types of livestock regions, a high LSU score per hectare is expected to also have a high share of maize. The numbers below confirm this argument. Especially the discrepancy between the heather-sprinkling region (0,5 LSU per hectare) and the fodder cultivation region(1,4 LSU per hectare), regarding that the LSU per hectare is of great relevance for this thesis. Due to the fact that, to raise the livestock maize is needed, this discrepancy explains why these two regions, even though they have such a high difference regarding the amount of biogas plants are so close by each other when it comes to the maize density within these regions.

Table 7. Maize density in Lower Saxony in relation to the LSU per hectare

	Lower Saxony	Cropland region	Fodder cultivation region	Heather-sprinkling-region	Refinery region
ø amount of Biogas Plants per district	32	8	18	41	70
Ø percentage of the cultivated land being used for the cultivation of maize	18,16	5,9	17,72	19,17	37,22
Ø LSU per hectare	0,9	0,3	1,4	0,5	1,7

Sources: Calculation of the author based on the data from: Niedersächsiches Ministerium für Ernährung, Landwirtschaft, Verbraucherschutz, und Landesentwicklung (2012) ,Höher (2012), Hiete (2009)

Thus as said within the theoretical chapter, factor conditions, or to say it differently, the availability of Maize can be considered to be influential on the development of the biogas sector within Lower Saxony, if the results show that more Maize is cultivated within those regions where biogas is more prevalent, than in those regions where biogas plays only a marginal role. The numbers presented above have clearly shown that more maize is cultivated within those regions where biogas is more prevalent, confirming a correlation between the maize density and the biogas plant density. However, the reason why the author of this thesis refrains from labeling this relationship a causal relationship is the influence of the refinery density on the maize density could not be fully controlled.

Additionally another finding of this analysis is that the availability of maize, and thus the density of biogas plants, heavily depends on the soil structure and connected with that, on the possibility for agriculturists to grow other more valuable crops.

4.3 Supportive and Related industry

The next attribute to be discussed is the existence of supported and related industry. As said in the theoretical chapter a high density of biogas constructing, consulting, and maintaining companies near biogas plants would be highly beneficial for the biogas plant operators. Thus, after having shown that the refinery region is the leader within Lower Saxony when it comes to biogas, it can be expected that in this region the most biogas facilitating companies would be located. Indeed the numbers below confirm this expectation; with 38 companies being located within the refinery region, the refinery region is home to more than half of the biogas related companies within Lower Saxony (73). The predominance of the refinery region in this context is even more obvious if one takes the mainly agricultural machinery maintaining company AGRAVIS, out of this list and focuses solely on those companies organized within the German Biogas professional association. 27 directly biogas related companies within the refinery region mean that 2/3 of the Lower Saxon biogas related companies can be found within the refinery region. Interesting to mention in this context is that, among those districts within the refinery region the district of Osnabrück has the highest density of biogas companies (9). Following Porter's (1990) line of reasoning, a possible explanation for the density of biogas companies within Osnabrück, is that the district of Onsabrück is the only district within the refinery region, where a university (Universität Osnabrück) as well as a university of applied since(Hochschule Osnabrück), is located. Both institutions are heavily connected with biogas, be it in terms of educating students (there are various, for biogas relevant bachelor and Master courses offered at both institutions such as Bio Sciences; Agriculture, Machine engineering, Bioprocess engineering, and Methods engineering) or be it in terms of doing research for improving the processes within biogas plants (main research projects: renewable energy systems; sustainable biogas production; faculty of agriculture; engineering faculty; biological and chemical faculty) and thus are, according to Porter (1990), and Etzkowitz (2008) of a great help for the nearby biogas companies and biogas plant operators.

Table 8. Supportive and Related Industry

	Lower Saxony	Cropland region	Fodder cultivation region	Heather-sprinkling-region	Refinery region
ø amount of Biogas Plants per district	32	8	18	41	70
Amount of companies related to biogas (consulting, constructing, maintaining) within the regions	73	11	9	15	38
biogas Companies (consulting, constructing, maintaining) listed within the professional association Biogas e.V. within the regions	40	2	3	8	27

Sources: Calculation of the author based on the data from: Niedersächsiches Ministerium für Ernährung, Landwirtschaft, Verbraucherschutz, und Landesentwicklung (2012) ,Fachverband Biogas (2013), Agravis (2013).

Thus, as said in the theoretical chapter, related and supportive industry can be considered as influential, if a higher amount of related and supportive biogas companies can be found within those regions where biogas is more prevalent than in those regions where biogas plays only a marginal role. The numbers presented above clearly indicate that the higher the density of biogas plants within Lower Saxony, the higher the density of supportive and related industry. Additionally it could be shown that most companies which are located in the refinery region are located in the district of Osnabrück. Following Porters (1990) and Etzkowitz (2008) a logical explanation for this observation would be that these companies benefit from the existence of the University of Osnabrück and the University of Applied Science of Osnabrück.

4.4 Rivalry

As said in the theoretical framework the rivalry between biogas plant operators can be best measured by focusing on the lease price for land. However, the table below which outlines the average price per hectare of agricultural usable land in 1999 and 2010, and the growth rate of the price within the different regions shows the difference between those regions with a high density of biogas plants and a low density of biogas plants are not as great as expected. Especially by comparing the Fodder cultivation region with the Heather-sprinkling region it becomes clear that an increase in price per hectare is not followed by an increase in the amount of biogas plants.

Table 9. Price increase in agricultural usable Land between 1999 and 2010

	Lower Saxony	Cropland region	Fodder cultivation region	Heather-sprinkling-region	Refinery region
ø amount of Biogas Plants per district	32	8	18	41	70
Ø price per hectare agricultural usable land in 1999 in euro	278,66	272,91	250,27	249,92	351,56
Ø price per hectare agricultural usable land in 2010 in euro	318,22	305,64	290,18	285,25	420
Increase in price per hectare agricultural usable land in percentage	14,18	11,90	15,96	14,19	19,44

Sources: Calculation of the author based on the data from: Niedersächsiches Ministerium für Ernährung, Landwirtschaft, Verbraucherschutz, und Landesentwicklung (2012) and the Landesbetrieb für Statistik und Kommunikationstechnologie Niedersachsen (1999, (2010)

The main reason to explain this trend is the usage of the indicator, which might not fully reflect an increasing rivalry among agriculturists. The problem encountered here is that with this method, one cannot exclude two other important factors which do influence the price development, of leased land, namely the refinery density and the quality of the soil. Therefore in order to check whether there is a higher rivalry within those regions where a lot of biogas plants are located, surveys, explicitly asking for whether agriculturists see an increasing

rivalry between each other, are needed. However, it remains questionable whether the results of the survey would confirm a higher rivalry within those regions where a lot of biogas plants are operational. The main reason for this skepticism regarding rivalry in this context can be found in table 10.

As said within the theoretical chapter, the other indicator that shall be analyzed in order to determine whether an increased rivalry can be observed within those regions where biogas is prevalent is the shutdown rate of agricultural holdings. However, by focusing on the results being presented in table 10, one has to admit that a higher percentage of shutdowns of agricultural holdings cannot be observed within those regions where biogas plays an important role, than in those regions where biogas plays only a marginal role. In contrast in those regions where biogas is mainly located the percentage of shutdowns is even lower.

Table 10. Development of Shutdowns of agricultural holdings within the different regions

	Lower Saxony	Cropland region	Fodder cultivation region	Heather-sprinkling-region	Refinery region
ø amount of Biogas Plants per district	32	8	18	41	70
Amount of agricultural holdings within the regions in 1999	69318	5359	10583	10927	15643
Amount of agricultural holdings within the regions in 2010	44001	3462	7081	7429	10622
Decrease in agricultural holdings in percentage	32,88	35,39	34,82	31.93	32,09

Sources: *Calculation of the author based on the data from: Niedersächsiches Ministerium für Ernährung, Landwirtschaft, Verbraucherschutz, und Landesentwicklung (2012) and the Landesbetrieb für Statistik und Kommunikationstechnologie Niedersachsen (2011).*

Thus based on these two indicators a higher rivalry could not be observed within those regions where biogas is of great relevance. Concluding from these results, there seems to be no relationship between rivalry among agriculturists and the increase of biogas plants within Lower Saxony.

5. Conclusion

One of the main aims of this thesis is to outline the causes which explain the rapid development of the Biogas sector within Germany. In order to find these causes this thesis started with a general description of the development of the German Biogas sector, and thus aimed to answer the first research question:

How did the Biogas sector develop within Germany between 2000 to 2011?

The findings on the development of the German biogas sector have shown that the German biogas sector grew enormously between 2000 to 20011. In the year 2000 only 1050 biogas plants, having an installed capacity of 65MW electricity, existed in Germany; this number increased over the following years up to 7215 biogas plants, having an installed capacity of 2009 MW electricity in 2011. In order to analyze the second research question:

What caused the increase of biogas production during the years 2000 to 2011 in Germany?

This thesis applied Porter's Diamond on the Lower Saxon Biogas sector. Attention was drawn towards the attributes/indicators presented in the table below. The findings of the analysis of these attributes/indicators, suggest, that, except for the attribute rivalry, all attributes listed within this table seem to have had influence on the Biogas sector within Lower Saxony.

Table 11. Overview of the different attributes/indicators that were analyzed and the their impact on the growth of the biogas sector within Lower Saxony

Attribute	**Indicator**	**Main Data source**	**Influential if…**	**Influential?**
Demand Conditions	Development of the EEG	1. BGBl 2. Fachagentur für Biogas e.V.	A significant increase in the growth rate of biogas plants after the amendments made on the EEG can be observed	Yes
Factor Conditions	Availability of Maize	1. Höher (2012)	More Maize is cultivated within those regions where biogas is more prevalent than in those regions where biogas plays only a marginal role	Yes
Related and Supported Industry	Location of Related and Supported Industry	1. Fachverband für Biogas e.V. 2. Agravis	A higher amount of related and supportive biogas companies can be found within those regions where biogas is more prevalent than in those regions where biogas plays only a marginal role	Yes
Firm Strategy, Structure and domestic rivalry	1.Price development for rented Land 2. Shut downs of agricultural holdings	1. Lower Saxon Statistical office	The price for rented agricultural land increased more within those regions where biogas is more prevalent than in those regions where biogas plays only a marginal role The shutdown rate of agricultural holdings is higher within those regions where biogas is more prevalent than in those regions where biogas plays only a marginal role	No

Source: Own Creation of the author

Based on these findings it is now possible to answer the third and last research question of this thesis:

What can be recommended to other European Governments who wish to increase the production of electricity generated from biogas

In order to give these recommendations in the most coherent way first of all will be the demand addressed, followed by factor conditions, the supportive and related industry and rivalry.

Demand

As outlined above, there is clear evidence that the artificial demand, created by the German Government with the help of the EEG, heavily boosted the German Biogas sector. From all attributes discussed in this thesis this attribute seems to have the biggest influence on the development of the German Biogas sector (C. Lacü, personal communication, June 10, 2013;

G., C. Höher, personal communication, June 13, 2013; M. Kralemann, personal communication, June 17, 2013). There are basically two reasons why the EEG has/had such a tremendous influence on the German Biogas sector. First of all, due to the introduction of several bonuses, agriculturists have the possibility to earn a lot more than they would receive, if they would sell their electricity at the free market. Secondly, a reason which should not be underestimated is the importance of receiving a fixed price over 20 years. As Lacü (personal commincation, June, 10, 2013) pointed out in an interview *"Especially within the agricultural sector, where the food price volatility is known for its unforeseeable developments, having a planning security over such a long timeframe means a big advantage for us biogas plant operators"*. The first recommendation to be expressed is thus:

Governments, who wish to increase the production of biogas within their countries, should set up a subsidies scheme for Biogas plants that is considerable above the price which could be received by biogas plant operators at the free market. With this higher price scheme biogas plant operators would be compensated for taking the risks and investing in this fairly new technology. Thereby governments should make sure that these prices are guaranteed over a time period of 20 years. With the introduction of this time frame, the government would first of all provide agriculturists an additionally incentive to invest in Biogas. But it would also mean that Biogas plant operators have an incentive to invest in further research and development, in order to be able to compete at the "free market", if the government signalizes (early enough) that after 20 years of paying subsidies no subsidies will be paid any more.

Factor conditions

As outlined above, there is clear evidence that where biogas plants are located maize is needed and thus is cultivated in huge amounts. Nevertheless there is also evidence found within this thesis, that those regions with a better soil structure, and thus higher earnings per hectare, are less likely to produce maize, given that they can produce better, more valuable crops such as cereals. Acknowledging this observation the second recommendation expressed within this thesis is:

Governments, who wish to increase the production of biogas within their countries, should implement subsidies schemes in a very careful way. Especially those countries which have a very favorable soil structure should take into account that "sacrificing" those granaries, and with them the secure supply of food, in order to generate energy, might not be desirable. Thus by designing a price scheme this thesis recommends government that this price scheme should, without any doubts be profitable for biogas plant operators, but it should, similar to the German system, not supersede the traditional objective of the agricultural sector, namely the cultivation of, for food relevant, resources, in those areas, where, due to favorable soil conditions the cultivation of, for food relevant, resources are very favorable.

Supportive and related industry

As shown regions within Lower Saxony which are leading with regard to the production of biogas usually have a higher density in their regions of biogas related companies (consulting, constructing, maintaining), than those regions where the production of biogas plays only a marginal role. Following the line of reasoning by Porter (1990) Lacü, (personal communication, June 10), Höher (personal communication, June 13, 2013), and Zietz (2013) this higher density of biogas related companies and shorter lines of communication are a clear advantage for biogas plant operators. The first recommendation regarding supportive and related industry is thus:

Governments, who wish to increase the production of biogas within their countries, should create favorable conditions for biogas related companies (consulting, constructing, maintaining). Tax incentives, or foundation bonuses, might therefore be proper means.

After introducing a rather neo-classical approach regarding the role of the government (tax incentives), within stimulating the regional growth, attention has to be drawn towards another observation made regarding supportive and related industry. As indicated above, there seems to be evidence that Universities can have a positive impact on the density of biogas related companies. Having noticed this, the second recommendation regarding the fostering of supportive and related industry builds up on the triple helix approach developed by Etzkowitz (2008).

Governments, who wish to increase the production of biogas within their countries, should try to give incentives to universities to install chairs that do research on topics relevant for biogas and share their knowledge with students.

Rivalry

With the results on rivalry of this thesis in mind, one can conclude that it seems that rivalry among biogas plant operators does not (yet) lead to a more developed biogas sector. Thus giving any recommendations to governments focusing on artificially increasing rivalry among biogas plant operators is not applicable. In contrast, by focusing on the suggestions by Höher et. al. (2011), it might be even questionable whether an increased rivalry would be desirable. Thus before recommending something which could have negative implications for the biogas sector further research on this topic needs to be done.

6. Limitations

This thesis has various limitations. The first one to be mentioned is, that by analyzing the development of the German Biogas sector, attention was only drawn on the growth of the sector; however, the cost of this growth, paid by the German energy consumer, was not balanced against the growth. There are various authors (Kaphengst 2007; Delzeit, 2011; Franzenburg, 2011; Frauenhofer Institut für Umwelt- Sicherheit- und Energietechnik, 2012) who argue that the development of the German Biogas sector came with too higher cost, and led to environmental damages (monocultures; increased pollution). More research on the (economically) effectiveness of the EEG as well as the environment impact would be needed in order to give desirable, more concrete recommendations.

The second limitation is that despite the logical argumentation of choosing Lower Saxony as case study, choosing only one Bundesland that shall represent the German Biogas sector limited (automatically) the external validity of the results. The results of this thesis would certainly have had a higher external validity, and thus be more generalizable for the German Biogas sector, if other Bundesländer would have been selected as well. However due to reasons of time and space this was not possible.

The third and last limitation to be mentioned is that it was not always possible to exclude, other factors that could have influenced the different attributes. Especially the results of the rivalry attribute, which might have been different if a more advanced measurement was applied.

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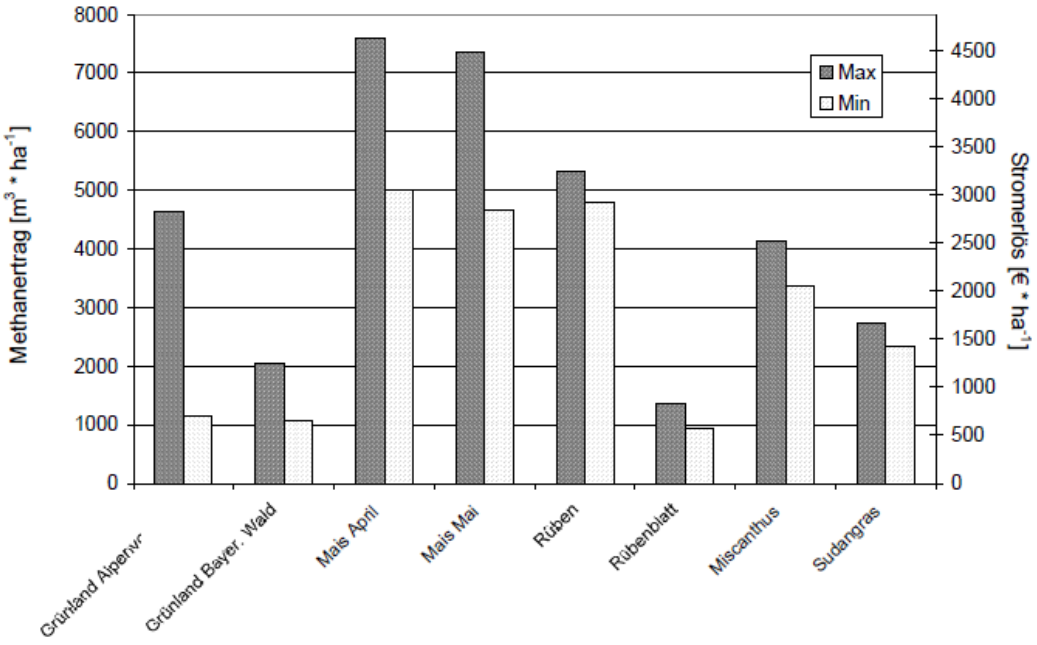
8. Appendix

1. *Methane Earning per hectare*



Source: Bayerische Landesanstalt für Landwirtschaft (2004)

2. *Interview Protocol*

Date of interview:

Name of interviewee:

Venue:

Time:

1. Brief introduction by the interviewer
    - Explain my role as a student (first research project, topic: biogas within Lower Saxony)
    - Explain purpose and use of interviews
    - Ask if audio taping and verbatim quotes are in order

2. Getting acquainted
    - What are your responsibilities within the Ministry of Agriculture/ 3N/Chamber of Agriculture
    - Since when are you in this position?

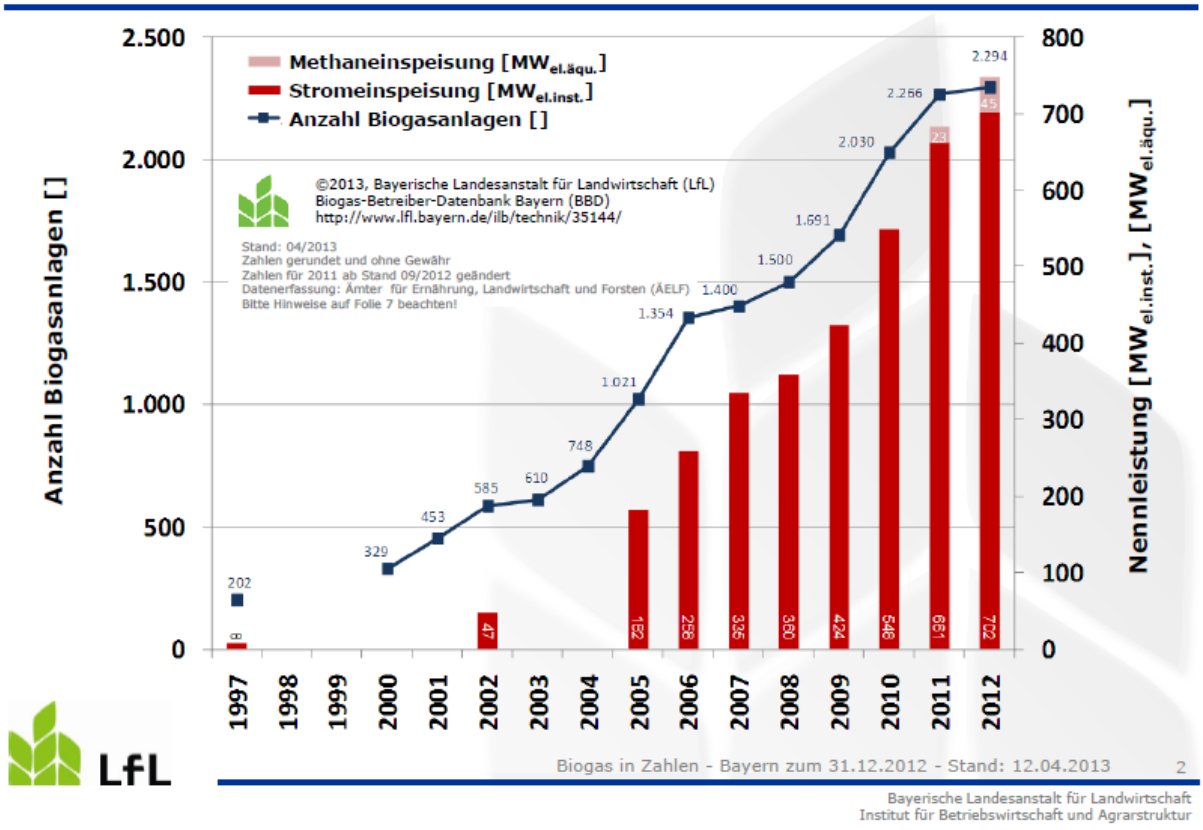
3. Porter's attributes:
    - Introducing Porter's Diamond to the interviewee

- Which of the four attributes did play the most important role in shaping the biogas sector of Lower Saxony, and why?
- Which of the four attributes did play the least important role in shaping the biogas sector of Lower Saxony, and why?
- Demand:
  - Which role did the EEG play in fostering the Demand?
  - Do you belief that the amendments made in 2004 and 2008 regarding the EEG did foster the amount of biogas plants within Germany?
- Availability of Maize:
  - How Important is the availability of maize for biogas plant operators?
  - Is there any substitute for maize among the Nawaros which is to be taken serious?

- Related and Supported Industry:
  - How important is a short distances (max 100km) between biogas plant operators and related and supportive industry (biogas consulting, construction etc.)?
- Rivalry:
  - Do you agree with the following statement:
    - Rivalry among biogas plant operators would be beneficial for the biogas sector
  - Is there an increasing rivalry among biogas plant operators visible?
  - Which role does the lease of land play?

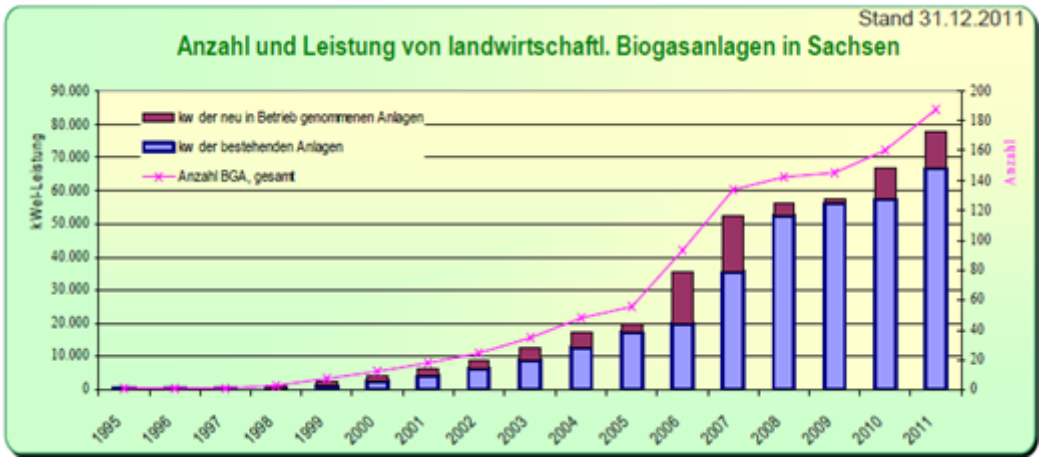
3. *Development of the amount of Biogas plants within Bavaria*

Abbildung 1: Zeitreihe zur Anzahl und Nennleistung der landwirtschaftlichen Biogaserzeugung in Bayern zum 31.12.2012



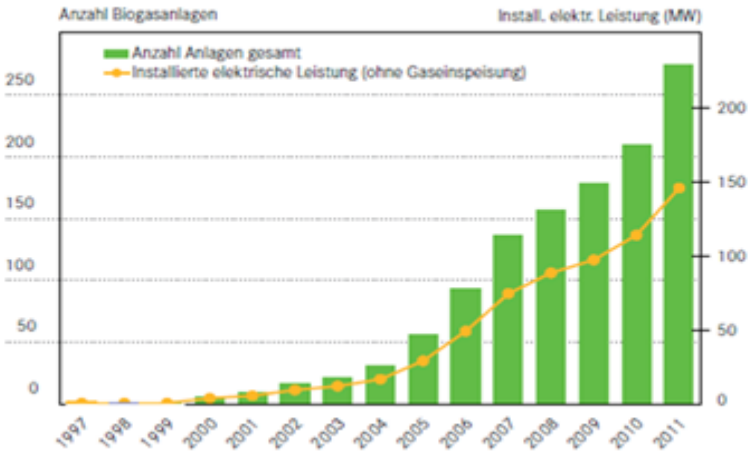
Source: Bayerische Landesanstalt für Landwirtschaft (2013)

4. *Development of the amount of Biogas plants within Saxony*



Source: Landesamt für Umwelt, Landwirtschaft und Geologie (2012)

5. *Development of the amount of Biogas plants within Saxony-Anhalt*



Source: Fachagentur Nachwachsende Rohstoffe (2012)

6. *Classification of the different districts into regions*

West (Refinery Region)	North West (Fodder cultivation region)	Centrum (Heather- sprinkling-region)	South East (Cropland region)
Emsland Grafschaft Bentheim Osnabrück Cloppenburg Oldenburg Vechta Diepholz	Leer Emden Aurich Wittmund Friesland Wilhelmshaven Wesermarsch Cuxhaven Ammerland Osterholz Delmenhorst Stade	Harburg Lüneburg Celle Heidekreis Uelzen Gifhorn Lüchow Dannenberg Nienburg Rotenburg Verden Region Hannover Peine Schaumburg Hameln-Pyrmont	Wolfsburg Braunschweig Salzgitter Wolfenbüttel Hildesheim Göttingen Northeim Osterode Goslar Holzminden Helmstedt

Source: Own creation of the author based on the results by Höher et al. (2011)

7. *Classification of the LSU system*

Bovine animals	Under 1 year old	0,400
	1 but less than 2 years old	0,700
	Male, 2 years old and over	1,000
	Heifers, 2 years old and over	0,800
	Dairy cows	**1,000**
	Other cows, 2 years old and over	0,800
Sheep and goats		0,100
Equidae		0,800
Pigs	Piglets having a live weight of under 20 kg	0,027
	Breeding sows weighing 50 kg and over	0,500
	Other pigs	0,300
Poultry	Broilers	0,007
	Laying hens	0,014
	Ostriches	0,350
	Other poultry	0,030
Rabbits, breeding females		0,020

Source: Eurostat 2013

8. *Tables indicating the data per district*

Name of the district	Biogasplants	installed MW	Maizedensity*	Soilpoints	t/ha Cereals	LSU/ha
Northeim	20	15	0,05	60	8	0,25
Holzminden	8	2,5	0,05	60	7,6	0,75
Osterode	0	0	0,05	60	7,3	0,25
Wolfsburg	2	2,5	0,05	40	6,2	0,25
Salzgitter	0	0	0,05	90	8,3	0,25
Wolfenbüttel	9	7,5	0,05	70	7,4	0,25
Göttingen	13	7,5	0,05	60	7,9	0,25
Helmstedt	6	2,5	0,05	50	7,1	0,25
Braunschweig	0	0	0,05	50	6,9	0,25
Goslar	8	2,5	0,05	60	7,8	0,25
Hildesheim	22	15	0,15	80	8,4	0,25
Regional Average**	8	5	0,059090909	61,8181818	7,53636364	0,29545455
Leer	13	2,5	0,15	40	7,3	1,625
Ammerland	22	7,5	0,25	30	5,3	1,625
Aurich	32	25	0,15	50	6,8	1,275
Wittmund	14	15	0,15	50	6,8	1,275
Wesermarsch	14	2,5	0,05	60	7,6	1,625
Delmenhorst	2	2,5	0,15	40	5,4	1,275
Friesland	14	15	0,15	60	7,5	1,275
Wilhemshaven	1	2,5	0,15	60	7,5	1,275
Stade	27	15	0,25	50	6,5	1,275
Cuxhaven	50	25	0,25	40	6,7	1,625
Osterholz	10	7,5	0,25	30	5,7	1,275
Regional Average**	18,09090909	10,90909091	0,177272727	46,3636364	6,64545455	1,40227273

Name of the district	Biogasplants	installed MW	Maizedensity*	Soilpoints	t/ha Cereals	LSU/ha
Hameln Pyrmont	22	15	0,15	60	7,8	0,25
Schaumburg	18	7,5	0,15	60	8,1	0,25
Hannover	30	15	0,15	50	7,2	0,25
Peine	10	7,5	0,15	60	7,6	0,25
Gifhorn	41	25	0,15	30	6,2	0,25
Uelzen	26	15	0,15	40	6,5	0,25
Lüchow Dannenberg	31	15	0,15	30	5,8	0,25
Lüneburg	24	15	0,15	40	6	0,25
Harburg	19	15	0,15	40	5,7	0,75
Celle	61	25	0,25	30	6	0,75
Heidekreis	69	35	0,25	30	5,4	0,75
Rotenburg	136	70	0,45	30	5,3	1,275
Regional Average**	40,58333333	21,66666667	0,191666667	41,6666667	6,46666667	0,46041667
Nienburg (Weser)	40	25	0,25	40	6,1	0,75
Verden	16	15	0,25	40	6,2	1,275
Osnabrück	66	35	0,35	40	6,6	1,85
Oldenburg	71	35	0,35	30	5,4	1,625
Diepholz	106	50	0,25	35	6,3	1,275
Emsland	146	70	0,45	30	5,3	1,85
Grafschaft Bentheim	45	25	0,45	30	5,1	2,25
Vechta	29	15	0,45	40	6,1	2,25
Cloppenburg	109	50	0,55	30	5,7	2,25
Regional Average**	69,77777778	35,55555556	0,372222222	35	5,86666667	1,70833333
Average within Lower Saxony	31,92770092	17,5581395	0,188652833	46,8445323	6,67496706	0,90724226

Name of the district	Rental Land Price***(1999)	Rental Land Price (2010)***	Growth in %	Agricultural Holdings 1999	Agricultural Holdings 2010	Decrease in %
Northeim	254	277		1057	631	
Holzminden	249	273		423	285	
Osterode	173	197		334	184	
Wolfsburg	189	219		120	69	
Salzgitter	339	408		123	81	
Wolfenbüttel	349	383		486	341	
Göttingen	227	259		914	564	
Helmstedt	270	298		430	300	
Braunschweig	275	309		124	63	
Goslar	307	344		354	247	
Hildesheim	370	395		994	697	
Regional Average**	272,909091	305,636364	11,9	5359	3462	35,39
Leer	281	323		1344	884	
Ammerland	253	304		995	664	
Aurich	240	285		1407	870	
Wittmund	268	311		845	545	
Wesermarsch	309	321		941	617	
Delmenhorst	244	248		81	47	
Friesland	303	321		678	440	
Wilhemshaven	173	262		63	39	
Stade	258	318		1220	908	
Cuxhaven	227	271		2209	1525	
Osterholz	197	228		800	542	
Regional Average**	250,272727	290,181818	15,96	10583	7081	34,82
Hameln Pyrmont	338	365		544	439	
Schaumburg	304	349		542	342	
Hannover	329	308		1659	1116	
Gifhorn	222	247		966	644	
Uelzen	281	337		692	559	

Name of the district	Rental Land Price***(1999)	Rental Land Price ***(2010)	Growth in %	Agricultural Holdings 1999	Agricultural Holdings 2010	Decrease %
Lüneburg	207	232		616	444	
Harburg	206	242		932	656	
Celle	191	246		675	441	
Heidekreis	171	216		965	671	
Rotenburg	214	271		2039	1279	
Regional Average**	249,916667	285,25	14,19	10927	7429	32
Nienburg (Weser)	264	313		1558	969	
Verden	220	255		854	537	
Osnabrück	356	447		2683	1808	
Oldenburg	358	274		1118	802	
Diepholz	335	401		2199	1343	
Emsland	380	505		2948	2000	
Grafschaft Bentheim	377	476		1227	951	
Vechta	431	552		1195	816	
Cloppenburg	443	557		1861	1396	
Regional Average**	351,555556	420	19,44	15643	10622	32.09
Average within Lower Saxony	278,658979	318,218874	14,18	69381	46566	32,88

* The term „Maizedensity“ refers in this context to the percentage of the agricultural usable land which is used for the cultivation of maize; **The term “regional average” refers, **except for the column “agricultural holdings “where total numbers are used,** to the regional average. *** The term “rented land prices”, refers to the amount of Euros which has to be paid by an agriculturists per hectare on an annually basis.

Sources: Own Creation of the author based on the data from: Hiete (2009), Landesbetrieb für Statistik und Kommunikationstechnologie Niedersachsen (2011), Niedersächsiches Ministerium für Ernährung, Landwirtschaft, Verbraucherschutz, und Landesentwicklung (2012), Höher (2012), Fachverband Biogas (2013), Agravis (2013)