Biogas policies, incentives and barriers

- a survey of the strategies of three European countries

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Sammandrag

Biogasproduktion för framställning av förnybar energi är en teknik med stor potential. Den producerade gasen kan användas för värmeproduktion, kraftvärmeproduktion, fordonsbränsleproduktion eller för att ersätta naturgas. Tekniken medför en positiv synergieffekt genom att utgöra en typ av avfallshantering, och det rötade materialet är dessutom en värdefull gödselprodukt.

En ökad biogasproduktion förespråkas på EU-nivå och i de flesta Europeiska länders strategier för förnybar energiproduktion. Trots detta går utvecklingen relativt långsamt och skillnader finns mellan olika ländernas inställningar till hur främjandet av tekniken ska gå till.

Målet med denna studie har varit att undersöka utvecklingen av biogassektorn i Europa. En översikt av situationen i EU och i tre valda länder – Sverige, Tyskland och Spanien – presenteras, och de olika strategierna för främjandet av tekniken beskrivs och diskuteras. Barriärer för den fortsatta utvecklingen av sektorn identifieras och sätt att komma förbi dessa hinder föreslås.

Arbetet har inletts med en litteraturstudie och sedan har intervjuer med nyckelpersoner i de tre länderna gjorts. Intervjuerna har varit mycket värdefulla för förståelsen av situationen i de undersökta länderna.

Den producerade mängden biogas samt produktionssätt och användning av gasen varierar betydligt mellan de undersökta länderna. Detta är ett resultat av olika uppfattningar om vad biogasen bör användas till, och av olika val av policies. Tyskland är den ledande biogasproducenten i Europa och bidrar med nästan hälften av den totalt producerade biogasmängden i Europa. Ett högt, stabilt elpris som garanteras producenten har givit en ökning av småskalig, gårdsbaserad biogasproduktion som inte finns i Sverige eller i Spanien. I Sverige har istället produktion av biogas som fordonsbränsle främjats vilket har gjort Sverige till ett föregångsland på detta område. I Spanien är biogasproduktion fortfarande en relativt ny teknik varför sektorn ännu inte har utvecklats i stor utsträckning. Stöd och initierande aktörer finns men den nuvarande ekonomiska krisen begränsar möjligheterna för utveckling i Spanien.

Många aktörer och samhällssektorer är involverade i biogasprojekt. Passande storlek på anläggningen och typ av teknik beror dessutom på den valda projekteringsplatsens lokala förhållanden. På grund av detta behövs olika typer av utveckling för att ta vara på hela potentialen, vilket i sin tur innebär att en mångsidig uppsättning policies och stödåtgärder är nödvändig. Lärdomar kan fås både från framgångsrik etablering i vissa länder och från exempel där åtgärder har visat sig inte fungera. Överföring av erfarenhet över gränserna är oumbärlig för att snabba på utvecklingen.

Nyckelord

Biogas, Europa, incitament, barriärer, fallstudier

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Abstract

Biogas production is a renewable energy technology of great potential. The produced gas can be used for heat production, combined heat and power production, vehicle fuel production or as replacement for natural gas. The technology brings about synergic benefits as it is a means of waste management and since the digested material is a valuable fertiliser.

An increased production of biogas is advocated on EU level and in the renewable energy production strategies of most countries in Europe. Nevertheless, the development is rather slow and differences in the approach to the promotion of the technology can be noticed in the different countries.

The aim of this study has been to investigate the development of the biogas sector in Europe. An overview of the situation in the EU and in three chosen countries - Sweden, Germany and Spain - is presented, and the strategies for promotion are described and discussed. Barriers for the continued development of the sector are identified, and ways to overcome these barriers are suggested.

The work has started off with a literature review after which interviews have been made with key persons in the countries. These interviews have been very valuable for the understanding of the situation.

The amount of biogas produced and the means of production and utilisation of the gas varies significantly among the investigated countries. This is the result of different views of what the biogas should be used for, and of different types of policies chosen. Germany is the leading producer of biogas in Europe, contributing to almost half of the total amount produced in Europe. A high, stable electricity price guaranteed to the producer has lead to a boost of small-scale agricultural biogas production not seen in Sweden or Spain. In Sweden the production of biogas as vehicle fuel has instead been promoted, making Sweden a leading country in this field. In Spain, biogas production is still a relatively new technology why the sector is not yet developed to a great extent. Support measures and initiating actors exist but the current financial crisis limits the possibilities for development.

Many actors and sectors of society need to be involved in biogas projects. The suitable type of technology or size of installation furthermore depend on the local conditions of the area chosen for the project. For this reason, different types of development are necessary in order to make use of the whole potential, which means a versatile set of policies and support measures is needed. Lessons should be learnt from both the successful implementation in countries and from examples of measures shown not to work. Transfer of know-how across the borders is essential for speeding up the development.

Keywords

Biogas, Europe, incentives, barriers, case studies.

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Preface

This thesis is the final part of a master degree in environmental engineering. It has been carried out at the Division of Environmental and Energy Systems Studies at Lund University. The thesis corresponds to 30 Swedish academic points, equivalent of 20 weeks of full-time studies, and the work has been carried out during May to December 2010.

I would first like to thank to my tutors Pål Börjesson and Mikael Lantz for always taking the time to give me very valuable comments on the text, and good advice during the work. Mikael has also helped me a lot by always knowing details about the Swedish biogas system - it has been very nice and convenient to share the office with you and Linda! Thanks also to everyone else at IMES for the warm welcome and the nice lunches.

I would moreover like to express my gratitude to the people I have had the opportunity to meet and interview. Hans Holland in Ochsenhausen has taught and shown me exactly how a farm-based biogas plant operates, and he has also given me information about the German biogas system which has been of great value for the investigation. I have also been very well received in Spain, first in Vila-Sana by Germàn Pinzano and thereafter by Laia Sarquella in Barcelona. Germàn deserves my gratitude for showing me the agricultural plant first built in Spain, and also for taking the time to tell me about the situation for biogas production in Spain. The interview with Laia gave me further information about the Spanish and Catalan biogas strategies, and has been of great help for the understanding of the system and of the future potential for biogas development in Spain. Finally, I would like to thank Mårten Ahlm in Malmö for a very interesting discussion about the Swedish biogas system.

Lund, December 2010.

Kristina Engdahl

Abbreviations and units used

AEBIOM: The European Biomass Association

CAP: The Common Agricultural Policy (EU)

CHP: Combined Heat and Power

EEG: The Renewable Energy Act (Germany)

GHG: Greenhouse Gas

KLIMP: The Climate Investment Programme (Sweden)

MW_p: Megawatt Peak

PV: Photovoltaic (electricity)

RD: Royal Decree (Spain)

RES-E: Electricity produced using Renewable Energy Sources

TWh: TeraWatt hour (1 TWh = 3.6 PJ = 0.086 Mtoe[1])

[1] AEBIOM, 2009.

Contents

1. Introduction

1.1 Background

Dependency on the use of fossil fuels is generally regarded as undesirable for several reasons. The climate change originating from the burning of these is one, the uncertainty of a continuous supply from the unstable fossil-fuel market is another. Moreover, the ecological tragedy earlier this year that was the consequence of a collapsed BP oil rig, show us that our dependency on oil results in further risks of a different character. The environmental costs of this accident are, as the costs of the climate change inevitably will be, of an immeasurable magnitude.

In the national and international plans for the development of the energy sector, an increased renewable energy production is often promoted as the given desirable progress. Benefits inherent in this development include a decreased dependency on import of energy, a way to avoid climate change and a job-creation opportunity. However, the often ambitious targets are many times not reached for different reasons. This recurrent problem needs to be examined in order for the desired development to take place.

The use of biogas as a renewable energy source is of fast growing interest. The biochemical process taking place during the anaerobic digestion is a natural mechanism and is in itself complex, but kept under the right conditions it will provide the combustible biogas without much additional input of work or energy. The scale of the technology can vary from simple constructions where the gas is only for household use, to large plants managing great amounts of wastes from society. The gas can be used as a combustible producing either solely heat, or heat and electricity in a combined heat and power (CHP) plant. Biogas can furthermore be used as vehicle fuel, and it can also be incorporated into the gas grid, replacing natural gas.

In addition to being considered a carbon-neutral energy source, biogas production is a means of waste management. Studies show that the amount of pathogens harmful to humans is reduced when treating manure by means of anaerobic digestion[1], which naturally is of importance for people in close contact with this type of waste.

The by-product from the biogas production is the digested material, known as the digestate. Since the process takes place in a closed system, no nutrients of the incoming material are lost, there is even an advantage in digesting the material as the digestion turn organically bound nitrogen into the water-soluble form ammonia. The ammonia is of easier access for the plants which means the digestate, when properly handled, is an excellent fertiliser[2].

It thus seems as though an expansion of the biogas sector is desirable for many reasons. Measures to promote the development are taken within the EU, among other things through directives such as the *Renewable Energy Directive*, which will be described later in this study. However, the introduction of the biogas technology is sometimes a slow process,

[1] Kearney et al., 1993; Weiland, 2009.

[2] Held et al., 2008.

due to different reasons in the different Member States. The development of the biogas production is complex as it involves many actors and sectors of society - agriculture, energy and waste management, for instance, and in order to evaluate the situation many aspects need to be considered. Some problems the biogas introduction may encounter are of local character whereas others may need solving at higher level, possibly through common legislation and other policy incentives.

1.2 Aim and method

The aim of this study has been to identify the existing incentives and barriers for the continued biogas development in Europe, and to discuss what ways would be the best to expand the implementation.

To investigate this, an overview of the conditions for biogas production in Europe was made, with focus on the following areas: renewable energy policies, waste management and agriculture. As the greatest potential for biogas production exists in the agricultural sector, most effort was throughout work on the report put on describing the conditions for this type of production.

Furthermore, the strategies for biogas promotion in Sweden, Germany and Spain have been examined. These countries were chosen because the development of the biogas sector has, so far, varied significantly between the countries. The geographic dispersion of the countries also implies that the local conditions may vary, and perhaps therefore a more comprehensive overview of Europe can be obtained.

A survey of the current situation in the three countries has been made, and incentives and barriers have been analysed. Comparisons between the strategies chosen by the countries have been made and the outcomes of these strategies discussed. Certain key questions were kept in mind during the course of work on the study:

- What types of technologies and biogas-production systems exist and what has made the development of this certain technology/system occur?
- Are the political strategies of the countries effective in expanding the implementation? Can any lessons be learnt from the outcomes of the various national strategies?
- What kind of political incentives and other driving forces seem to be the most effective ways to continue the development of the biogas sector in a broader perspective, for instance, on the EU level?

In order to get an overview of the conditions for biogas production and utilisation in the EU and in the investigated countries, the project started with a literature review. To obtain an investigation as comprehensive as possible, qualitative interviews were thereafter conducted with key persons in the different countries. From the interviews further details of the different strategies were obtained, and barriers for the continued development could be identified. Based on the literature review and on the interviews, a multidisciplinary systems analysis was finally made.

1.3 Disposition

Chapter 2 presents an overview of the conditions for biogas production in the European Union. Renewable energy policies, waste management policies and agricultural policies are investigated with focus on factors that may affect the development of the biogas sector. The same structure is applied in Chapter 3 in which case studies are made of the biogas systems of Sweden, Germany and Spain. Barriers affecting the production and the utilisation of biogas are described in the end of each case study.

In Chapter 4 the results from the case studies are summarised, analysed and discussed. Identified incentives and barriers are divided into categories which are thereafter discussed. The chapter is ended with a list of conclusions possible to draw from the case studies.

Chapter 5 discusses factors and issues that are of a more general character and often of a global perspective, but that affect the development of the biogas sector nevertheless.

Final and general conclusions from the study are made in chapter 6.

2. Conditions for biogas production in the European Union

In 2005 the *Biomass Action Plan* was issued by the Commission, pointing at the great potential of biomass utilisation for renewable energy production - a potential increase from the consumption of approximately 800 TWh (2,900 PJ) in 2003 to a contribution of around 2,200 TWh (7,900 PJ) in 2010 was shown. However, no targets for biogas production in itself can be found in this document since biogas is categorised as a type of renewable energy originating from biomass. As this represents various technologies it is difficult to distinguish what part biogas production per se is to play in the future European energy system. Anyhow, it is clear that an expansion of the use of biomass is advocated in the plan[1].

Calculations made recently by AEBIOM, the European Biomass Association, show a biogas potential of around 460 TWh (1,700 PJ) by 2020 in the EU-27. For this production agricultural products (for instance energy crops and manure) and waste (biodegradable waste and sewage sludge) are to be used as substrates. Recovery of landfill gas is also included in this potential. The potential production would be equivalent to a third of the natural gas production in Europe, and 10 % of the consumption[2]. Another estimation, from Eurobserver, is that the biogas production will amount to approximately 90 TWh (330 PJ) in the EU by 2010, an increase from 70 TWh (250 PJ) in 2007[3].

According to the *Renewable Energy Road Map* issued in 2006 by the Commission, the electricity produced through biogas combustion in the EU-25 was about 15 TWh_e per year in 2005, and the production is projected to increase to around 90 TWh_e per year in 2020[4]. In Ragwitz et al.[5], the development of the electricity production from renewable energy sources is simulated and presented in two future scenarios: one business-as-usual scenario and one policy implementation scenario. The results of this study show that in the business-as-usual scenario the electricity production coming from biogas is likely to four-fold to 36 TWh_e by 2020, whereas the biogas production increases to 57 TWh_e in the policy scenario[6].

According to these studies, biogas production is thus likely to increase rapidly in the future if the development is to correspond to targets set and estimations made.

[1] The European Commission, 2005.
[2] AEBIOM, 2009.
[3] EurObserv'ER, 2008.
[4] The European Commission, 2006.
[5] 2005.
[6] Ragwitz et al., 2005.

2.1 Renewable energy policies

The understanding of the problems connected to energy supply has made the use of renewable energy sources a part of the debate in the European Union. In 1997 the *White Paper on Renewable Energy Sources* was issued by the European Commission giving renewable energy production high priority. A target was set to use 12 % renewable energy sources in the energy system by 2010. This was not a legally binding target, rather a political tool. Having a concrete target was also a way to prepare for the Kyoto meeting taking place later in 1997[7].

In 2001 a goal which more specifically concerned electricity production was set in a directive by the European Parliament and the Council - by 2010 22 % of the electricity produced was to originate from renewable sources[8]. However, by 2007 the share amounted to 15 %[9], and according to a prediction stated in the *RES Directive*[10] a 19 % share would be reached with the current measures taken[11].

To develop the sector the *Renewable Energy Road Map* was issued in 2006 by the European Commission, in which is stated: *The EU has compelling reasons for setting up an enabling framework to promote renewables. They are largely indigenous, they do not rely on uncertain projections on the future availability of fuels, and their predominantly decentralised nature makes our societies less vulnerable. It is thus undisputed that renewable energies constitute a key element of a sustainable future.* In this report the ambitions are high - for instance, the large investments in coal and nuclear power made in the past are compared to the large investments in renewable energy needed today. Fundamental changes in policies are also stated as necessary for the desired transition to a sustainable society[12].

In the *Renewable Energy Directive* from 2008, known as the *RES Directive*, a binding target for all Member States is proposed. Each country is to reach a 20 % share of renewable energies in the total energy consumption by 2020. In the transportation sector the share of biofuels is to amount to 10 %. This to reach the overall target of a 20 % share of renewable energies in the energy system of the Union by 2020. In order to reach these targets, all Member States are obliged to assemble national *Renewable Energy Action Plans*. The plans were to be submitted to the Commission by the end of March 2010[13].

2.2 Waste management

Different types of waste from society are of great importance when studying biogas systems. By utilising organic waste for biogas production it could be regarded as a resource instead of as a problem, but this change in perception is taking its time, and large amounts of organic residues are still being disposed of in other ways, such as composting or landfilling.

Nevertheless, the concept of “reduce, re-use, re-cycle” is not new within the European countries. Already in 1975 the Council of European Communities declared that firstly prevention of waste production is necessary and secondly, that the produced waste must be handled in an appropriate manner: *Member States shall take appropriate steps to encourage the prevention, recycling and processing of waste, the extraction of raw materials and possibly of energy therefrom and any other process for the re-use of waste*[14]. However, these

[7] The European Commission, 1997.
[8] The European Parliament and the Council of the European Union, 2001.
[9] Europe's Energy Portal, 2010a.
[10] The European Commission, 2008a.
[11] The European Commission, 2008a.
[12] The European Commission, 2006.
[13] The European Commission, 2008a.
[14] The Council of the European Communities, 1975.

ambitious goals have not been reached and the production of waste in the OECD European countries has increased continuously since 1975. Moreover, landfilling and incineration are still the predominant ways of handling municipal solid waste, and furthermore, waste still escapes to less developed countries[15].

Organic waste is not exempted from the complex of problems regarding waste. The methane emissions from organic material ending up in landfills accounted for 3 % of the total greenhouse gas emissions of the EU-15 in 1995. An attempt to handle this problem is the *Landfill Directive* which obligates the Member States to by 2016 have reduced the biodegradable waste in landfills to 35 % of the amount 1995[16].

In 2008 the *Green Paper on the management of bio-waste in the European Union* was issued by the European Commission to further discuss the issue of organic waste management. One aim of the paper is to prepare for a debate over whether a common policy within the Union is needed concerning bio-waste. Anaerobic digestion is in this report being classified as both recycling (when the digestate is used as fertiliser) and as energy recovery, and the positive GHG-saving effects the biogas utilisation would propose when substituting conventional vehicle fuel is also mentioned. Nevertheless, composting is still the most common means of biological treatment, in 2006 it accounted for 95 % of the total amount treated[17].

In the same Green Paper the results from a study made by the European Environment Agency are mentioned. This study showed that out of the 20 % renewable energy that will have to be produced in the Union to reach the 20/20/20-goal, 7 % could come from utilising waste. The calculations in the study are based on assumptions that all waste now going to landfilling would be incinerated with energy recovery, and that all material now going straight to composting would be anaerobically digested beforehand. By this way of reasoning it seems as though biogas production would be the preferred way of dealing with the organic waste. Later in the Green Paper this is confirmed: *Due to the energy recovery potential from biogas coupled with the soil improvement potential of residues (especially when treating separately collected biowaste) it may often represents the environmentally and economically most beneficial treatment technique*[18].

The Animal By-product Regulation

In the EU regulation known as *Regulation (EC) No 1774/2002* or the *ABP-regulation*, the proper handling of animal by-products is described, and the residues are categorised. This in order to prevent the spreading of animal diseases, such as BSE and foot and mouth disease. The regulation affects the biogas production since residues such as slaughterhouse waste, which is an energy-rich substrate, in many cases needs pre-treatment according to the directives. Table 2.1 below, adapted from Kirchmayr et al., shows the different fractions and the pre-treatment necessary for the use of these[19].

Category 1 includes material with a high risk of contamination of the above mentioned diseases. Notable in Table 2.1 is that there is no obligation to hygienisise manure before digestion. Residues from the food industry, on the other hand, must be pasteurised according to the regulation[20]. The residue obtained after digestion of material that belong to category 2 and 3 can be used as fertiliser[21].

[15] The European Environment Agency, 2010.
[16] The European Commission, 2010a.
[17] The European Commission, 2008b.
[18] The European Commission, 2008b.
[19] Kirchmayr et al., 2003.
[20] Kirchmayr et al., 2003.
[21] The Ministry of Environment, Rural Surroundings and Marine, 2010a.

Category	Material
Category 1	Not designated
Category 2 without preliminary treatment	Manure as well as digestive tract content (separated from the digestive tract; if there is no risk of disposal of serious diseases), milk and colostrum
Category 2 after sterilisation with steam pressure and marking (with smell)	All materials classified as Category 2 (e.g. perished animals or animals slaughtered, but not intended for human consumption)
Category 3 in a biogas plant approved in accordance with Article 15 of the Regulation	All materials classified as Category 3 (e.g. meat containing wastes from the foodstuff-industry, slaughterhouse wastes of animals fit for human consumption)
Category 3 in biogas plants which are to be approved in accordance with provisions and methods to be adopted or which are approved according to national legislation	Catering waste (except from international means of transport)

Table 2.1: Survey of materials designated for treatment in biogas plants.

2.3 Agriculture

The Common Agricultural Policy

The *Common Agricultural Policy*, the *CAP*, was introduced in Europe after the Second World War in order to help the agricultural sector recover from the extensive damage the war had caused, and to feed the affected population. The system of production subsidies remained unchanged for decades, eventually leading to an overproduction of agricultural goods in Europe which, in turn, has resulted in further problems[22]. For instance, the system has been heavily criticised for distorting the world food markets through a combination of export subsidies and the selling of overproduced food at very low prices. Since the domestic goods, produced in countries outside of Europe, cannot compete with European goods, farmers in poorer countries cannot earn their living, and consequently cannot feed their families or develop their farming[23]. These important problems connected to the CAP lie, however, outside the scope of this study.

One measure taken within the CAP in order to limit the over-production is an obligation for farmers to set-aside land. In 1999/2000 it was decided that 10 % of the arable land was to be permanently set-aside, in 2007 this area amounted to 3.8 million hectares[24]. In 2008 the obligation to set-aside land was, however, abandoned[25]. The set-aside land policies are of importance for the energy crop production discussion, which in turn may affect the biogas sector. The issue of land-use will be discussed further in Chapter 5.

In 2003 there was a reform of the CAP with the intention of making it more demand oriented by connecting the subsidies more to the incomes of the farmers than to the quantity

[22] The European Commission, 2010b.
[23] Paasch, 2010.
[24] EU Press release, 2007.
[25] The European Commission, 2007b.

produced[26]. Biogas production per se is not mentioned in the reformed CAP. However, a key element of the new CAP is a rural development strategy, in which renewable energy production from agricultural products is advocated[27]. In 2004 a support for cultivation of energy crops was introduced as a part of the CAP, the *Aid for energy crops*. 45 Euros per hectare was offered and up to 2 million hectares could be cultivated in the Union[28]. The support was discontinued in 2009 as the Commisson considered the energy crop sector in no further need of support[29].

Ecological farming

Included in the CAP is an obligation for the Member States to set up *agri-environment schemes*, and farmers are then granted support when fulfilling measures included in the schemes. One such measure is conversion to ecological farming, this concept is advocated in all Member States[30].

Biogas production at ecological farms is an interesting field which could have great potential as it may bring about positive synergy effects. Since mineral fertilisation is not allowed when practising this type of cultivation, the digestate obtain a high value as fertiliser. As mentioned earlier in the study, the digestion process transforms the nitrogen in the incoming material, making it of easier access for the plants. If, furthermore, ley crops for digestion are included in the crop rotation, beneficial soil properties can be achieved, for example by a reduction in root weeds[31].

At the Swedish Agricultural University in Alnarp, experiments with digestate were carried out in 2002. Two lanes of cultivation were compared: in lane A, conventional ecological agricultural methods were used, for instance, tilling of tops, leaves and straw into the soil. In lane B, these residues, as well as the ley crops cultivated firstly in the crop rotation, were instead digested, and the digestate obtained was used as fertiliser. The result of the study showed up to 24 % higher yields, as well as a higher content of protein, of the crops harvested in lane B[32].

[26] The European Commission, 2010b.
[27] The Council of the European Union, 2006.
[28] The European Commission, 2007a.
[29] The Council of the European Union, 2009.
[30] Gay et al., 2005.
[31] The Ecological Farmers, 2008.
[32] The Swedish Board of Agriculture, 2006.

3. Case studies of three European countries

The amount of biogas produced in the different countries of the European Union varies considerably, as do the means of production and end-use. Different incentives bring about different technological solutions - a fixed high price for produced electricity, for instance, favour CHP production whereas other incentives may instead encourage production of vehicle fuel. However, in the current situation the majority of the biogas produced in Europe is used for electricity and heat production. The performance of the plant is usually shown in [kWh_e produced], and not in [amount of material treated], which reflects this fact[1]. For this reason the reader will notice that, in the texts dealing with the countries where CHP production is the main utilisation of biogas, the policies regarding electricity production and distribution will be analysed in more detail than the polices for other types of production systems. What type of production assessed to be most efficient will be discussed later in this report, this depends largely on the production system and on the local conditions.

Table 3.1 below shows figures of the primary energy production of biogas 2008 in the countries examined in this study and in the European Union. The figures are expressed in GWh and the share of the total amount of biogas produced in the country is shown within brackets. *Sewage sludge* includes both urban and industrial sludge, and *Other* includes biogas produced in decentralised agricultural plants, municipal solid waste methanisation plants and centralised co-digestion plants[2].

Country	Landfill	Sewage sludge	Other	Total	Per cap.
Germany	4000 (9 %)	4590 (11 %)	34200 (80 %)	42700	0.52
Spain	1830 (77 %)	229 (10 %)	309 (13 %)	2360	0.053
Sweden	267 (22 %)	666 (56 %)	265 (22 %)	1200	0.13
EU	33900 (39 %)	11600 (13 %)	42200 (48 %)	87700	0.18

Table 3.1: Production of biogas in the countries analysed in the study, expressed in GWh. The per capita production is expressed in GWh per 1000 inhabitants.

Notable in Table 3.1 is that 77 % of the biogas production in Spain consisted of landfill gas and since landfilling is now to be reduced according to the Landfill Directive[3], the production of this type of gas should decrease in the future. When looking closer vertically at the columns, it is remarkable that approximately 80 % of the European *Other* production consists of the German production, and that almost 50 % of the total production can be

[1]EurObserv'ER, 2008.
[2]EurObserv'ER, 2009.
[3]The European Commission, 2010a.

attributed to Germany.

Both Germany and Spain have autonomous regions with fairly large possibilities of self-governance. This means the conditions for biogas production may vary within the country due to regional differences in legislation and support measures. In Germany a fair-sized amount of support is generally given on the regional *Länder-level*, but since some regions have been more active in the promotion than others, regional differences exist[4]. In Spain the biogas development has taken place in Catalonia to a larger extent than in the other autonomies. This since the Catalan support system is more developed than elsewhere, and also because of private initiatives in the region[5].

The investment is relatively large for an installation of a biogas plant - in Spain and Germany the cost for small-scale plants varies between 4,000 and 5,000 Euros/installed kW[6]. This means an installation of 500 kW, which would generally be regarded as a fairly large farm-based plant, has an investment cost of between 2 and 2.5 million Euros.

As is notable in Table 3.1 the biogas production differs significantly between the investigated countries, both in terms of quantity produced and in the means of production. In the following sections the systems of the different countries will be examined in more detail in order to understand why the current situation has come about. To get an overview of the systems, as comprehensive as possible, certain key areas will be analysed in detail. These areas include:

- An introduction in which a description of the current situation for biogas production in the country is given, and the general conditions for biogas production are discussed.
- An overview of the national political incentives and other factors that affect the biogas production. The policies described regard renewable energy, waste management and agriculture.
- A summary and discussion about existing and potential barriers for the development of the biogas sector. The information in these texts will be based largely on interviews with experts, in different ways connected to the biogas industry in the countries examined in this study. The questions on which the interviews were based and a table of all potential barriers can be found in Appendix. Both incentives and barriers can be divided into groups of those that affect the *production* of the biogas and those that affect the *utilisation* of the gas[7].

[4]International Energy Agency, 2010j.

[5]Sarquella, 2010.

[6]Sarquella, 2010; Pinzano, 2010; Holland, 2010.

[7]Lantz et al., 2006.

3.1 Sweden

The Swedish per capita production of biogas is slightly lower than the average European per capita production, see Table 3.1. The biogas production was initially introduced in various municipalities as a way to handle waste streams, such as sludge and organic household waste. Upgrading of biogas to vehicle-fuel quality has also been initiated on a municipal level in many cases[8].

According to a survey made by the Swedish Energy Agency, 1.36 TWh of biogas was produced in 2008. The majority of the 227 existing biogas plants were treating sewage or were utilising landfill gas, and it is remarkable that there were only eight agricultural plants. 53 % of the gas was used for heating, 26 % was upgraded and used as vehicle fuel, 4 % was used to produce electricity and 14 % was flared. The digestate produced amounted to around 413,000 tonnes and the main substrates used were sewage sludge, organic household waste and organic waste from the food industry[9]. Only small amounts of energy crops were used for digestion, around 100 tonnes, produced at one farm-based facility[10].

The production of biogas from agricultural facilities is, as seen in the figures above, limited. It is, however, in this sector the largest potential for development is assessed to be. According to Linné et al., the technical potential for digestion of cultivation residues and manure is 8.1 TWh. In the same study is estimated that approximately 0.8 TWh of biogas could be produced from the digestion of food residues. The collection of source separated organic household waste should increase as most regions in Sweden have the ambition to apply this system of waste management[11]. If, furthermore, 10 % of the total area under cultivation in Sweden, which is currently not cultivated, could be used for energy crop production for biogas purposes, another 7 TWh could be produced[12].

A suggestion for a new Swedish biogas strategy

In August 2010, a strategy for the future biogas development in Sweden was suggested. The strategy has been developed by the Swedish Energy Agency in cooperation with the Swedish Board of Agriculture and the Swedish Environmental Protection Agency. The potential for biogas production is estimated to be between 3 and 4 TWh in a near time perspective and based on current conditions, out of which 2.5 TWh could come from further digestion of sludge and waste streams from society, and 700 GWh could come from digestion of manure. The potential is thus, in this case, assessed to be considerably lower than the potential suggested by Linné et al. This may be explained by the fact that, in the strategy, the economic potential is assessed to be significantly lower than the technical potential.

Important suggestions of the strategy include:

Economic incentives:

- Digestion of manure is to be supported by an extra 2 eurocents per kWh of energy produced.
- It is to be further investigated whether digestion of ley crops can be promoted by extra support. A support for cultivation of ley crops used for feed already exists, and this support could apply for cultivation of ley crops for biogas production as well.

[8] Grontmij, 2009.
[9] The Swedish Energy Agency, 2010b.
[10] Grontmij, 2009.
[11] Linné et al., 2008.
[12] Benjaminsson et al., 2007.

- A tax on mineral fertilisers is advocated to indirectly increase the value of the digestate.
- It is recommended that the incentives are strengthened for the production of biofuels in general.
- By advantageous taxation it could become more attractive to use biogas as fuel in heavy-vehicle local traffic.

Research and development:

- Research should be focused on making existing facilities more efficient and to develop the small-scale technology.
- It is suggested that more research should be done on different digestion processes.
- Means of guaranteeing high-quality digestate are to be further investigated.

Structural changes:

- A system of rules for connection to grids (electricity, gas and district heating) is to be introduced.
- To further integrate biogas production in society the municipal plans for sewage treatment and waste treatment are to be connected to the energy planning.
- Actors involved in all parts of the biogas production and utilisation chain are urged to cooperate in order to achieve an efficient system.
- It is promoted to make use of advantages of scale and common utilisation.
- Conversion of tractors and trucks to operation using biomethane should be encouraged.

It is currently not known which of these suggestions will be implemented, but according to Ahlm, project manager at *Biogas Syd* in Malmö, it is likely that at least some will be realised. In the last budget proposal, most information regarding biogas referred to the strategy[13].

It is clearly stated in the strategy that waste streams, primarily, are to be used as substrates in the production, and that the handling of these is to be promoted. According to the study, the use of energy crops for biogas production should not receive economic support; neither should the production of biomethane, the upgraded biogas. No concrete target is set for the amount biogas produced, this because it is seen as unnecessary since the biogas production being economically feasible will develop regardless of what targets exist[14]. The strategy has for this reason been criticised by Ullberg[15], communication manager at *Energy Gas Sweden*. Ullberg also questions the fact that only digestion of manure is to receive economic support and not, for instance, organic household residues which contain large amounts of energy. Furthermore, no special focus is put on promoting the production of biomethane[16].

[13] Ahlm, 2010.
[14] The Swedish Energy Agency, 2010a.
[15] Baltscheffsky, 2010.
[16] Baltscheffsky, 2010.

Regional biogas organisations - Biogas Syd

In order to connect the different actors involved in the biogas sector, six organisations exist that work on the promotion of biogas in Sweden, covering different regions from North to South. For instance, in the South, *Biogas Syd* previously mentioned has played this role since 2005. Members of Biogas Syd include energy companies, public authorities, the Farmer Association, one university, various municipalities and the regional public transport company.

Aims are to increase the interest for the technology, and to support and help actors interested so that factual implementation of the projects is possible. Promotion and information about the means of utilisation are also central tasks. One example of a project by Biogas Syd is a course in farm-based biogas production. The course is divided into two parts - one basic course where interested may determine whether biogas production is possible at the own farm, and after this, a second more in-depth course for farmers who want to proceed the planning of a project. According to Ahlm, there is an interest among farmers for biogas production. As the profitability of the different agricultural activities varies, having an extra project can be valuable. Many farmers also have a general concern and interest in the environment[17].

3.1.1 Renewable energy policies

A target set by the Swedish government is that there are to be no further emissions of greenhouse gases by 2050. To reach this goal, the greenhouse gas emissions are to be reduced with 40 % by 2020, and this reduction is to be realised through economic incentives. Such incentives are, among other things: a carbon dioxide tax, a closer relation between the vehicle tax and carbon dioxide emissions, a reduction of the carbon dioxide tax for environmentally sound vehicles, a system of green certificates and measures in developing countries[18].

By 2020, 50 % of the total energy use is to originate from renewable energy sources, and 10 % of the transport sector is to use renewable fuels. According to the government, one of the ways to reach these targets is to promote all types of gas utilisation, and by way of introduction have natural gas play an important role in the transition[19].

Economic drivers

In Sweden, a general energy tax has existed for decades. The size of this tax depends, among other things, on the energy content of the fuel. In addition to this, a carbon dioxide tax and a sulphur tax were introduced in 1991, and in 1992 a nitrous oxide fee was added to the sum. In 2009, the carbon dioxide tax amounted to around 10.5 eurocents per kilogram of carbon dioxide, and the sulphur tax to approximately 3 Euros per kilogram sulphur emitted from combustion of coal and peat. For oil, around 2.7 Euros was to be paid per cubic meter, for each tenth of a percent unit (weight) of sulphur content of the oil. Biogas production is indirectly favoured by these taxes since renewable energy production is excluded from the taxes[20].

To promote electricity produced from renewable resources, a market-based system of green certificates, also called electricity certificates, has been introduced. The aim of the system is to increase the production of RES-E to 17 TWh by 2016, compared to the

[17] Ahlm, 2010.
[18] The Swedish Government, 2009.
[19] The Swedish Government, 2009.
[20] The Swedish Energy Agency, 2009.

production of 6.5 TWh in 2002. In 2008 the electricity production, covered by the system, amounted to 14.2 TWh meaning that the increase until then had been 7.7 TWh. For each produced MWh the RES-E producer receives a certificate which can be sold to the electricity suppliers. The suppliers are obliged to buy certificates to cover a certain quota of their sold electricity, in 2007 this quota was 15.1 %. Since the system is market based, so is the price of the certificates. In February 2008, the price was approximately 3.5 eurocents per kWh, which can be compared to a price of approximately 1.5 eurocents in the middle of 2006[21]. The price for sold electricity varies according to the prices of NordPool, the Scandinavian electricity spot market. Since 2004 the electricity price has been varying in a range of 1.5 to 9 eurocents per sold kWh[22]. Thus, if producing electricity in Sweden using biogas, the income for the sold electricity has varied between 3 and 12.5 eurocents per produced kWh. It is of great importance to be able to sell, or at least use, the heat produced[23].

To encourage investments in energy technologies not yet competitive on the market but which bring about benefits for the climate, the *climate-investment programme*, known as *KLIMP*, previously existed. The programme was of importance for the biogas development - a third of the KLIMP subsidies were used for biogas projects[24]. The subsidies were generally used by municipalities and bigger companies, and not by individual farmers[25].

Since November 2009 there is a new form of support for the generation, distribution and use of biogas, through *Ordinance (2009:938)*. The aim of the measure is to make the new technology commercially viable. The subsidy can cover up to 45 % of the costs entitled to support according to EU regulations, and has a ceiling of 2.5 million Euros. In 2009, 10 million Euros were dedicated to this purpose, supporting 10 projects[26]. However, there were applications summing up to an amount ten times higher than the size of the subsidy[27].

Between 2006 and 2009 a grant existed for installing pumps supplying biofuels other than ethanol, retailers at 144 locations received this grant for the installation of biogas pumps[28].

Economic support for farm-scale biogas installations can currently be obtained from the *Rural Development Programme* within the CAP. Between 2009 and 2013 the total amount allocated to this specific type of biogas production is approximately 20 million Euros[29]. Not many new plants have been constructed so far making use of this support but it is, however, not unknown of since concerned actors have distributed the information[30]. This investment subsidy is described in further detail in section 3.1.3 below.

In Sweden there is a definition for “environment vehicles” which include, among others, cars with a low usage of fuel or cars driving on ethanol or gas (natural gas/biogas in the current situation). The owner of an “environment car” enjoy certain benefits such as free parking and exemption from the congestion charge in Stockholm. If the car is an official vehicle, it can be purchased for the price of an equivalent conventional car[31]. Owners of official environment cars furthermore pay a lower tax imposed on fringe benefits, 20 % and

[21] The Swedish Energy Agency, 2009.
[22] Swedish Energy, 2010.
[23] Lantz, 2004.
[24] Grontmij, 2009.
[25] Ahlm, 2010.
[26] The Swedish Energy Agency, 2010c.
[27] Ahlm, 2010.
[28] The Swedish Government, 2010.
[29] The Swedish Government, 2010.
[30] Ahlm, 2010.
[31] miljöfordon.se, 2010.

40 % lower for ethanol cars and gas-driven cars, respectively[32]. Moreover, between the 1^{st} of April 2007 and the 30^{th} of January 2009, an investment subsidy of approximately 1000 Euros was given to environment-car purchasers[33]. From January 2010 the vehicles are instead exempted from the vehicle tax during the first 5 years[34], and from 2012 purchasers of new types of "super-environment cars" are promised an investment subsidy of approximately 4000 Euros. Which cars will be classed as "extra environmentally friendly" is yet unclear, but electrical cars and biogas cars with CO_2-emissions of less than 50 g/km have been mentioned. The Swedish government estimates that around 5000 of these cars will be sold as a result of the support[35]. The new system has been criticised for only focusing on this small share of the Swedish vehicle fleet (0.5 %), a fleet which to a large extent consists of fuel-guzzling cars. Conversion of these to running on biofuels is, however, not considered necessary by the Swedish government[36]. From the beginning of 2011 economic support can instead be obtained for the conversion of tractors to driving on biogas - approximately 1.8 million Euros will be invested for this purpose[37].

3.1.2 Waste management

In order to accomplish one of the Swedish environmental goals, *A good built environment*, a target regarding waste is set to biologically treat 35 % of the organic residues coming from households, restaurants and canteens by 2010[38]. In 2008 20 % of this material was treated in such a way[39].

If by-products from the meat and the dairy industry, such as slaughterhouse waste or manure, are used in the biogas production, there is in many cases an obligation for hygienisation of these materials, according to the *animal by-product ordinance*. The material is hygienisised by heating up to 70°C for one hour, and the particle size must be less than 12 mm. Digestion of manure from the own farm, and possibly from some farms close by, is exempted from this obligation, as well as digestion of meat residues from the food industry[40].

3.1.3 Agriculture

A potential 70 % of the substrates used in the Swedish biogas production could come from agricultural residues, but in the current situation only 1 % of the total biogas production is farm-based[41].

Regarding the role of the agricultural sector in the biogas development of Sweden, a report ordered by the government, *SOU 2007:36*, investigates the future potential of bioenergy using agricultural resources. In the investigation is ruled out that the conditions of the market are to primarily decide the agricultural land-use. However, it is also stated that in some cases it may be motivated to politically support some technologies in order for these to develop[42]. For this reason it is suggested that manure-based digestion is to receive extra support and a subsidy can currently be obtained covering 30 % of the investment cost.

[32] Börjesson, 2010.
[33] The Swedish Environmental Department, 2010.
[34] The Swedish Energy Agency, 2010d.
[35] Rabe, 2010.
[36] Lagercrantz et al., 2010.
[37] The Agricultural Business Magazine, 2010.
[38] The Swedish Energy Agency, 2010a.
[39] The Swedish Environmental Department, 2009.
[40] The Swedish Board of Agriculture, 2010a.
[41] Grontmij, 2009.
[42] The Swedish Government Official Reports, 2007.

At least 50 % of the substrate used should consist of manure, but other mixes of substrates can also be approved. In most cases, up to 1.8 million SEK (around 200,000 Euros) can be attained for each project[43]. The support is a part of the above mentioned EU rural development programme[44]. Also in the Swedish rural development plan for 2007-2013, the *Countryside programme*, biogas production is advocated as a special priority/focus area. It is mentioned as a sector that could provide jobs and market opportunities for the agricultural businesses[45].

With the aim of creating a more local connection to different projects in rural areas and to create job opportunities, the *Leader programme* has been applied in the EU since 1991 and in Sweden since 1996. It is a method to create economic, ecological and social rural development through cooperation between voluntary, private and public actors, taking much consideration to the local conditions and the view of the public living in the area. Financing comes from private investors, the state, the EU and the municipality. The projects receiving the support are chosen by a local group consisting of actors from the three above mentioned sectors[46]. One example of a biogas project receiving Leader-support is a pre-study of the conditions for biogas production using manure in a region of Southern Sweden[47].

The only type of energy crop production supported financially in Sweden is salix. The chips are combusted to produce district heating, for this reason this support does not affect the biogas sector[48].

3.1.4 Barriers for further development

From the reasoning so far can be concluded that biogas production in Sweden is generally regarded as something positive, and that a development of the sector is advocated. However, according to Ahlm, the discussions are often on a theoretical level, and there is a lack of will to actually find the existing problems and try to solve them. Decisions should be made so that the development is possible also in reality[49].

Barriers affecting the production

- **The projects are not economically feasible:** According to Ahlm, there is a limited investment capital for biogas projects as it is a new and unknown of business, the market can be regarded as immature[50]. This means there is no established market for the technology which makes it expensive. A development of the market would lower the prices, but in the current situation investment subsidies are motivated.

  There is, moreover, a lack of long-term perspective in the investments. The same problems apply for the biomethane market, the costly upgrading pose a barrier for the feasibility of the projects[51].

  There is an obligation for hygienisation of manure if more than a few farms are to co-digest produced manure. The extra cost the pretreatment entail may be a large part of the budget for "medium-sized" facilities where, for instance, five farms cooperate.

[43] The Swedish Board of Agriculture, 2010b.
[44] Grontmij, 2009.
[45] The Agricultural Department, 2009.
[46] Leader Ystad-Österlenregionen, 2010a.
[47] Leader Ystad-Österlenregionen, 2010b.
[48] The Bioenergy Portal, 2010.
[49] Ahlm, 2010.
[50] Ahlm, 2010.
[51] Ahlm, 2010.

In the case of smaller installations, pretreatment is not necessary, and in the case of large-scale facilities the cost for pretreatment is usually not great in relation to the whole investment[52].

- **Problems with bureaucracy and permissions:** The time needed for the permission process depends on the region - in the most Southern part of Sweden, for instance, it can take up to one year. In other regions, however, the process can run more smooth and half a year may be sufficient for the handling[53].
- **Competition with other technologies:** In some cases there is a competition between biogas production and incineration of household wastes[54].
- **Instability in policies:** There is a lack of policies with a long-term time perspective, as can be noted in section 3.1.1. The energy and CO_2 taxes can be regarded as stable, it can even be presumed that these will increase but this is, however, not sufficient for a development of the biogas sector[55].

Barriers affecting the utilisation

- **Lack of infrastructure:** There are logistic barriers in many parts of the biogas chain. The dispersion of the raw material is sometimes an issue, and as natural gas is not commonly used in Sweden, there is a gas grid only on the west coast. There is, furthermore, a lack of filling stations for biomethane which is a problem of significant importance in Stockholm. The market for gas-driven cars is small but growing[56].
- **Difficulties in utilising the heat and digestate produced:** If CHP production at farm-based facilities is applied, it is often difficult to utilise the heat produced. This problem is naturally more significant in summer time[57].

  There is usually not a problem to utilise the digestate produced as long as the facilities are not extremely large. It is, however, sometimes difficult to get a "proper" income from the selling of the digestate as its value has not been commonly known of previously, why a low price is standard[58].
- **Problems when connecting to the electricity grid:** As the electricity producer has to pay for the connection to the electricity grid, this may impose an extra cost if connection is only possible at a point far from the biogas facility. This should, however, normally not be an issue as most agricultural practises already use large amounts of electricity[59].
- **Competition with other technologies:** For the utilisation of biomethane there is a competition with natural gas, but not to a large extent[60]. The problem is, however, not insignificant on the west coast where the natural gas grid is extensive as the natural gas is still cheaper than upgraded biogas[61].

[52]Lantz, 2010.
[53]Lantz, 2010.
[54]Lantz, 2010.
[55]Lantz, 2010.
[56]Ahlm, 2010.
[57]Lantz, 2010.
[58]Lantz, 2010.
[59]Lantz, 2010.
[60]Ahlm, 2010.
[61]Lantz, 2010.

3.2 Germany

Germany is the largest producer of biogas in the European Union, both in terms of net production and in terms of per capita production, as is illustrated in Table 3.1. In 2008 the biogas plants amounted to 3891 units, producing approximately 10 TWh_e[62]. The majority of the biogas is produced in smaller farm-scale plants, in 2007 this means of production amounted to 71.2 % of the total production[63]. The agricultural biogas production is regarded as having the largest development potential: out of a total technical potential of 417 PJ from sewage gas, landfill gas and agricultural biogas, the latter could provide 77-85[64] %, according to Poeschl et al. In the same report it is estimated that only 10 % of the total technical potential for biogas production is currently utilised[65]. There is, however, a growing interest for biogas production among younger farmers. Many see more future in biogas production than in the dairy-cattle industry, and if a single farm-scale plant is not suitable, projects of community plants occur. Regarding larger scale plants, the energy companies themselves are often owners or part owners of the plants[66].

In the current situation, 33 % of the substrates used in Germany consist of energy crops. The remaining substrates used consist of 51 % agricultural residues, 11 % municipal residues and 5 % industrial residues[67]. CHP production is still the main utilisation of the gas, but biomethane production is since 2008 encouraged by given primary access to the natural gas grid where a large share of the cost is to be paid by the grid operator. This gives the biomethane the equivalent advantage RES-E has benefited from in the electricity sector. The system of RES-E access to the grid is described further in the coming section. The aim of this new strategy, implemented by law, is to achieve a 10 % share of biomethane in the gas mix by 2030[68]. The upgraded gas is currently not used as vehicle fuel to a significant extent[69].

Regional biogas organisations - Fachverband Biogas

The *Fachverband Biogas* is the German interest organisation for the promotion of biogas. One aim is to connect operators, producers and projectors and to spread the knowledge gathered in the organisation since the start in 1992. Another function of the organisation is lobbying on the federal and regional level. Fachverband Biogas is the largest biogas organisation in Europe with 3,900 members and as it is defined as working for "tax-exempted privileged causes" active work is done to avoid working for the economic interests of the organisation[70].

3.2.1 Renewable energy policies

As a result of the EU *Climate and Energy Package* in 2009, and of negotiations on the national level, the German government has set up general targets regarding energy use. One of the goals set is to use 30 % renewable energy in the electricity production and 14 % in the heat production, both by 2020. Furthermore, an increase in the use of renewable energy in the transport sector is advocated, 7 % of the total reduction of greenhouse gases

[62] Poeschl et al., 2010.
[63] EurObserv'ER, 2008.
[64] Poeschl et al., 2010.
[65] Poeschl et al., 2010.
[66] Holland, 2010.
[67] The Ministry of Environment, Rural Surroundings and Marine, 2010a.
[68] EurObserv'ER, 2008.
[69] Holland, 2010.
[70] Fachverband Biogas, 2010

is to come from an increased utilisation of biofuels. Also, the view of the environmental benefit of biofuels is to change from the current focus on energy content, to a focus on the net greenhouse gas reductions the use of the biofuel in question entails. It is moreover stated that the use of bioenergy could be doubled. Wood is described as preferential for heat production, biogas for CHP production and oilseed plants for biofuel production. Introducing biogas to the natural gas grid is also stated as a key development factor[71].

There is a political will to develop the district heating network in Germany as it is an efficient way to use excess heat, for instance from the extensive CHP production using biogas. New systems are constructed, and there are already existing grids in Eastern Germany remaining from the Soviet period. These could be reactivated to make use of produced heat[72].

In 2009 the renewable energy consumption in Germany amounted to 10.1 % of the total energy consumption of 4,870 PJ. Biomass is the most important renewable energy, contributing with 7 % of the total amount. 93.5 TWh renewable electricity was produced, out of which 10.7 % can be attributed to biogas production[73].

Economic drivers

The conditions for producing renewable electricity in Germany has for a relatively long time been advantageous compared to the situation in other countries. Initially mainly wind power and photovoltaic electricity were produced as a result of the support measures, but the biogas sector has also developed considerably. The most prominent part of the system is the feed-in tariff which has been successful for the implementation of projects, and of great importance for the biogas development. For this reason, a description of the development of this system follows.

Already in 1991 the *Electricity Feed-In Law* was implemented, giving RES-E primary access to the grid and also ensuring producers a premium, also called tariff, for the electricity produced. The premium consisted of a percentage of the mean specific income earned by the electricity supplier the previous year. For example, small-scale biogas ($<$500 kW_e) received 75 % of the mean specific income. After 1996 the tariffs decreased following a reduction in electricity price due to the liberalisation of the electricity market, and also because of the termination of a previously existing coal levy[74].

In 1998 the system changed so that the regional grid operators were obliged to buy only 5 % of the renewable electricity produced in their district. If more than 5 % was produced in the region, the obligation to buy the produced electricity was passed to the grid operator one level higher, this company had to buy another 5 %. This system was introduced to limit the inequality of the financial burden for grid operators in certain regions, which had evolved with the previous system[75]. The efficiency of this new system, also known as the double-cap system, can in retrospect be discussed. Agnolucci[76] uses wind power as an example. With this system the quota was almost filled up in windy regions which indirectly benefited development in less advantageous regions, but it also acted as a barrier for further development in the windy northern regions.

However, in 2000 the Feed-in Law was replaced by the *Renewable Energy Act (EEG)* in which the main principles were kept but the “5 %-system” was excluded. The aim of the EEG was to double the share of renewable electricity produced in Germany by 2010 (to

[71] Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2010b.
[72] Holland, 2010.
[73] Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2010c.
[74] International Energy Agency, 2010g.
[75] International Energy Agency, 2010g.
[76] 2005.

12.5 %) and instead of the double-cap system a new system was introduced: this time all electricity suppliers in the nation were expected to provide the same share of RES-E in their electricity mix. To accomplish this there was an obligation to purchase the excess RES-E, if needed, at a price decided as the mean price for all renewable electricity produced[77]. This correlates to another new feature of the system - consideration was now taken to the cost of production by differentiating the tariffs depending on the technology and the size of the installation. Moreover, by changing the tariffs from being connected to the retail price of RES-E to being connected to the price of production, the uncertainty following dependency on the market was removed. The tariffs were guaranteed for up to 20 years, with a tariff reduction, however, for new facilities ranging between 1 and 5 % per year, depending on the technology. Also, the conditions for renewable electricity production were still advantageous in that RES-E was given primary access to the grid[78].

The EEG is still in force but certain amendments were made in January 2009 as a result of implementing an *Integrated Climate Change and Energy Programme* in Germany in 2007. The amendment favour most types of renewable energy production by increasing the tariffs. Biogas from biomass receives a higher tariff than that for landfill gas, mine gas and sewage gas, and the annual degression of the tariff for this type of biomass biogas is lowered to 1% per year[79]. Table 3.2 below shows the different tariffs for biogas production, expressed in eurocents per kWh.

Type of plant	**Agricultural**	**Landfill**	**Sewage**
Basic tariff	7.79 - 11.67	6.16 - 9	6.16 - 7.11
Manure bonus (>30 %)	1 - 4	-	-
Plant material bonus	1 - 2	-	-
Air quality bonus	1	-	-
Technology bonus	1 - 2	1 - 2	1 - 2
CHP bonus	2 - 3	-	-
Energy crop bonus	7 - 11	-	-

Table 3.2: Feed-in tariffs in Germany, expressed in eurocents/kWh.

Most of the figures[80] in Table 3.2 depend on the size of the plant in question. Agricultural plants are devided into groups of < 150 kW$_e$, 150-500 kW$_e$, 500 kW$_e$- 5MW$_e$ and 5 MW$_e$-20 MW$_e$, where the smaller facilities receive the higher tariffs[81].

The air quality bonus is received if the amount of formaldehyde emitted in the process is limited to amounts according to standards of 2002. The plant material bonus can be obtained if the main substrate used is coming from the cleaning of natural green spaces. The technology bonus is introduced to encourage the use of innovative technique, and fermentation of organic waste is included in this bonus. In the same way the CHP bonus is introduced to premier this type of production. The energy crop bonus is received when conventional energy crops are being digested, but also for digestion of manure in combination with certain plant-based by-products[82]. The energy crop bonus is not received in the

[77] International Energy Agency, 2010h.
[78] Agnolucci, 2005.
[79] International Energy Agency, 2010i.
[80] Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2010a; EurObserv'ER, 2008; German Energy Blog, 2010.
[81] Agnolucci, 2006.
[82] Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2008.

case of co-digestion with slaughterhouse waste[83]. Biomethane production receives a bonus of 1-2 eurocents/kWh[84].

A small-scale agricultural plant operator could thus receive up to approximately 30 eurocents/kWh_e if energy crops and manure are digested and the electricity is generated by a CHP engine.

RES-E that is not included in the EEG system can be sold as *Green electricity* at a higher price. This electricity has, however, only reached a limited share of the power market. In 2000, for instance, it only amounted to 1 %[85]. Another feature of the German electricity market is the *Eco-tax*. Biofuels are exempted from this tax but electricity generation is affected by the tax regardless of the means of production. However, RES-E producers pay a lower tax than fossil fuel electricity producers[86]. The renewable electricity production is, furthermore, partly compensated for the tax through the *Market Incentive Programme*, financed by the revenues from the eco-tax. The programme offers grants for small facilities, and favourable loans for larger installations[87]. The loans can be taken from the *Reconstruction Loan Corporation (KfW)*, with interest rates usually 1 to 2 % lower than the market rate, and the credit terms of the loan last between 10 and 20 years[88].

3.2.2 Waste management

The majority of the waste produced in Germany is currently disposed of in composting facilities, but a transition towards digestion of the material is advocated in a research report commissioned in 2005 by the German Federal Environmental Agency. The same report shows a considerable reduction of landfilling in Germany between the years 1990 and 2005, and the emissions of greenhouse gases originating from this practice were reduced from 39.23 to 0.09 million tonnes CO_{2eq} during this period[89].

Standards for the use of treated organic material as fertiliser are set in the *Biowaste Ordinance* from 1998. The ordinance is under revision, and the new version will include, among other things, information about hygienisation requirements of biowaste for aerobic and anaerobic treatment[90].

3.2.3 Agriculture

In 2008 the German government issued a report concerning the connection between climate change and agriculture. Manure management contributed to 8 Mt CO_{2eq} out of a total of 110 Mt CO_{2eq} coming from agricultural practices. Means described to handle this problem concern manure storage: *Gas-tight storage of manure, preferably via co-fermentation in biogas plants, reduces CH_4 and N_2O emissions from manure storage.* Biogas production is thus indirectly advocated in this report. Cultivation of perennial crops for renewable energy production is also considered as part of a more sustainable agricultural sector[91].

In the production of agricultural biogas it is common to cultivate energy crops which are co-digested with manure and/or other residues. It is estimated that an area of 400,000 hectares is used for cultivation of energy crops specifically for biogas production in the

[83] Holland, 2010.
[84] EurObserv'ER, 2008.
[85] International Energy Agency, 2010k.
[86] Holland, 2010.
[87] International Energy Agency, 2010m.
[88] International Energy Agency, 2010l.
[89] Dehoust et al., 2005.
[90] The European Compost Network, 2010b.
[91] Federal Ministry of Food, Agriculture and Consumer Protection, 2008.

current situation[92]. The total area used for energy crop production in Germany amounts to 2 million hectares, which is equivalent of 12 % of the area used for cultivation. According to Germany's Renewable Energy Agency, 4.4 million hectares could be used for this purpose by 2030[93]. It is thus likely that energy crop production for digestion will increase. The extensive monocultural production of corn silage for biogas production has, however, started to entail environmental problems such as soil degradation and the introduction of fungi and pests. Moreover, people are starting to object the extensive cultivation because of the optical change of the landscape. Research is carried out to find other plants, or mixes of plants, to substitute some of the corn silage production[94].

3.2.4 Barriers for further development

In the end of 2007 there were 3,750 agricultural plants in Germany, 250 new plants were built this year. Even though this is a relatively large number of plants constructed, the growth rate decreased remarkably from 2006 when 800 plants were constructed. This decrease was due to a double of the price of energy crops used for biogas production, and also because of an increase in the price of biogas plants due to an increasing demand for these[95]. In a report from 2010, Poeschl et al. lists both drivers and barriers in the production and utilisation of biogas in Germany, with the conclusion that even though Germany may be the leading country in terms of production, much can still be done to harness the total biogas potential. Also in this report is indicated that the uncertainty in the price of energy crops may act as a barrier. The means of energy crop production must also be considered as monocultures, as mentioned above, have a negative impact on the environment[96].

Barriers affecting the production

- **The projects are not economically feasible:** According to Poeschl et al., additional costs may arise both in the handling of substrates in need of pre-treatment, and also in the education of personnel in order to achieve a safe and efficient process. Furthermore, the spreading of digestate can be costly as well as the investments in storage for the substrates[97]. The large investment may also act as a barrier according to Holland[98], ecological farmer owning and operating a 70 kW biogas plant in Ochsenhausen. A new obligation for additional safety regulations of the plants has made the price increase.

- **Problems on the local level:** The public opinion of biogas projects has become less positive with time, according to Holland. There is a perception of biogas production as being something which smells, makes noise and bring about traffic, and accidents at plants has made some think of the technology as being dangerous. For this, it may be difficult to build plants close to villages. This may imply an additional problem since it is easier to get an outlet for the heat produced when in closer connection to a village with district heating[99].

[92] Poeschl et al., 2010.
[93] Germany's Renewable Energy Agency, 2010a.
[94] Holland, 2010.
[95] EurObserv'ER, 2008.
[96] Poeschl et al., 2010
[97] Poeschl et al., 2010.
[98] Holland, 2010.
[99] Holland, 2010.

- **Competition with other technologies:** Competition with incineration and composting may act as a barrier, according to Poeschl et al. This problem is, however, estimated to decrease in the future as incineration plants impose gate-fees to handle substrates (as opposed to biogas plants), and, in the case of composting, there is often a need for pre-treatment of the substrates[100].

Barriers affecting the utilisation

- **The biomethane projects are not economically feasible:** Factors such as high investment costs for upgrading facilities and competition with cheap natural gas act as barriers for gas-grid injection of biogas, according to both Poeschl et al. and Holland[101]. Similar barriers exist in the utilisation of upgraded biogas as vehicle fuel. Among the biofuels, biomethane is the most expensive, and there are limitations in the distribution since filling stations are scarce[102].

- **Difficulties in utilising the heat produced:** Making use of the heat produced in off-site CHP facilities may be difficult, and mobile heat storage is costly[103]. This fact is confirmed by Holland, and it especially applies for large plants that produce great amounts of heat[104].

- **Problems when connecting to the gas grid:** Through the above mentioned new legislation, there is an obligation to allow connection to the natural gas grid. However, since biomethane is more expensive than natural gas, grid operators are not positive to the development since there is yet no great public demand for green gas in Germany. There is thus a risk of a problem similar to that previously taking place in the RES-E sector, as some grid operators may have to buy large amounts of biomethane and for this reason feel unjustly treated[105].

[100] Poeschl et al., 2010.
[101] Poeschl et al., 2010; Holland, 2010.
[102] Poeschl et al., 2010.
[103] Poeschl et al., 2010.
[104] Holland, 2010.
[105] Holland, 2010.

3.3 Spain

Biogas production is a new technology in Spain, a fact confirmed by the low amount of gas produced - the per capita production is much lower than the average European per capita production, see Table 3.1. The first agricultural plant was built in 2006 in Catalonia, with a 382 kW CHP engine[106]. Another five farm-scale plants have been built, treating manure and other organic by-products from the agriculture. All of these plants use CHP engines with an installed power of less than 500 kW. Facilities of larger scale managing urban organic residues also exist, but not to a large extent[107].

Out of the approximately 25 % share of renewable energies in the Spanish electricity mix in 2009, biogas production accounted for 0.2 %. However, in the *National Renewable Energy Action Plan (PANER)* of Spain, issued in June 2010, biogas production is described as a technology of great potential which have thus far not developed to its full extent[108].

Electricity production through combustion of biogas is one of the advocated ways to reach the first goal of the Spanish *Renewable Energies Plan*, the *PER 2005-2010* described in more detail below. The use of biogas for vehicle fuel production is, however, never mentioned in this report. A target is set to produce 1.7 TWh (6.3 PJ) gas by 2010, where 37 % is to come from the recovering of landfill gas, 49 % from sewage treatment, 5 % from livestock production waste and 18 % from industrial waste[109].

The development of the biogas utilisation was substantial between 1998 and 2004, the installed power increased from 33 to 141 MW during this period. However, the use of landfill gas accounted for 80% of this increase - by 2004 the target for landfill gas recovery mentioned above was reached easily, fulfilling its goal by 317 %. This stands in great contrast to the targets of biogas production using waste from the livestock industry and from sewage treatment, only fulfilling their goals by 6.8 % and 5.4 %, respectively[110].

More recent figures show that the goal set in the PER 2005-2010, to have an installed biogas and biomass capacity of 250 MW, is not fulfilled. According to APPA (The Association of Producers of Renewable Energies) 12.5 % of the renewable electricity production is currently coming from combustion of biogas and biomass, but the initial ambition was that the use of these were to cover 42.2 % of the production[111].

Nevertheless, the potential for biogas production in Spain is substantial. In calculations of the potential for 2010, made by AEBIOM, the Spanish potential is the third largest in EU-27, the potential is estimated to be larger only in Germany and France. For the calculations it is assumed that 5 % of the arable land can be used for energy crop production which could be used for co-digestion with 35 % of the available manure. This would give a biogas production of 38 TWh (140 PJ) in Spain[112].

In the very most cases, CHP generation is the means of utilisation of the biogas in Spain. Upgrading of the gas in order to distribute it on the natural gas grid is not yet common since the grid operators consist of a few companies unwilling to let biogas enter the grid[113]. The use of biogas as biofuel is only taking place in a limited amount of buses in Barcelona and Madrid[114].

[106] Pinzano, 2010.
[107] Sarquella, 2010.
[108] The Ministry of Industry, Tourism and Commerce, 2010.
[109] The Institute for the Diversification and Saving of Energy, 2005a.
[110] The Institute for the Diversification and Saving of Energy, 2005a.
[111] The Association of Producers of Renewable Energies, 2010.
[112] AEBIOM, 2009.
[113] Pinzano, 2010.
[114] The Ministry of Environment, Rural Surroundings and Marine, 2010a.

Regional biogas organisations - Probiogas

To promote the production of biogas from agroindustrial waste the project *Probiogas* was initiated in 2007. The involved actors consist of 15 research centres and 16 companies, all contributing with different technical and scientific knowledge within the area. The aim of the project is *the development of sustainable systems for production and use of biogas in agroindustrial surroundings, and by this demonstrating the feasibility and promotion in Spain*[115]. Through subprojects the situation in Spain is to be investigated, and figures of how much accessible substrate there is in each municipality can already be found on the website. Other subprojects include studies of what type of co-digestion would be most efficient, how to demonstrate the value of the digestate better and a study of what would be the best way to use the produced biogas. All systems studied and promoted through Probiogas are using the technology co-digestion, meaning that more than one substrate is used to obtain a high gas yield[116].

Figures of available substrates can be found on the website of *Probiogas*. Every year around 49 million tonnes of manure is produced in the livestock industry. A large amount of organic waste is also accessible in the vegetable and fruit production, for instance, products overproduced or not fitting in aesthetically. Waste is also generated in the processing of these greens, and in the biofuel and meat-production industries[117]. For some substrates, the biogas producer attains an additional income for the treatment of the waste; this gate-fee can be up to 30 Euros per tonne. This income may be of importance for the total profitability of a biogas project[118].

3.3.1 Renewable energy policies

In February 2009 the Spanish government issued the *Draft bill for a Sustainable Economy*, a package of structural changes to try to tackle the ongoing financial crisis that is currently affecting Spain immensely. The draft bill consists of three main pillars, one being *committing to environmental sustainability*. This aim is to be fulfilled through, among other things, sustainable transportation, an increased amount of renewable electricity generation and an increased environmental tax deduction[119].

Previous targets for renewable energy production include the Spanish commitment to the European Union, that 12 % of the total energy consumption is to come from renewable energy sources by 2010. This was to be fulfilled through the *Spanish Renewable Energy Promotion Plan (2000-2010) (PFERE 2000-2010)*, but in 2004 it was, nevertheless, becoming evident that Spain was not going to fulfil this commitment due to an increase in energy consumption not matched by a corresponding increase in the use of renewable energy. New measures were needed and the *Plan for Renewable Energies in Spain 2005-2010* (PER 2005-2010) was issued as an updated version of the PFERE 2000-2010[120], with indicative targets and common administrative standards for the autonomous regions[121]. In the PER 2005-2010, additional targets are set for 2010, among other things that 29.4 % of the electricity production is to come from renewable energy sources and that 5.75 % of the vehicle fuel used is to consist of biofuel[122].

[115] Probiogas, 2010. Translation by author.
[116] Probiogas, 2010.
[117] Probiogas, 2010.
[118] Sarquella, 2010.
[119] GLOBE, 2009.
[120] The Institute for the Diversification and Saving of Energy, 2005a.
[121] International Energy Agency, 2010c.
[122] The Institute for the Diversification and Saving of Energy, 2005a.

Economic drivers

Also in Spain a feed-in tariff system is applied, which has made Spain a leading country in terms of installed power of wind and PV, 1610 and 2671 MW_p, respectively in 2008[123].

Already in 1980 the concept of electricity produced in the *special regime* was established in Spain. Classification of small-scale hydro power and self-generated electricity, and promotion of these types of electricity production, was an attempt to tackle the second oil crisis by becoming more self-sufficient. The concept developed during the 90's and in 1994 new means of production were included: additional renewable energy sources, co-generation power plants, large-scale hydro power and power plants making use of residual heat. In 1997 it was decided that producers of special regime-electricity, provided that the facility had an installed capacity of 50 MW or less, were to be guaranteed a price matched by the market and a bonus when selling surplus electricity produced.

Through the *Royal Decree 436/2004*, the system was developed further, making it possible to sell the produced electricity at a regulated tariff which was fixed during the agreed period[124]. The tariff consisted of a percentage of an *Average or Reference Tariff*, also known as the TMR, and was approximately 7.30 eurocents/kWh in 2005[125]. The producer could also choose to sell the electricity on the market. In this case, an additional bonus for entering the market was given, as well as a bonus for producing special regime electricity[126].

When the *Royal Decree Law 7/2006* was issued, calling for urgent measures to promote renewable energy in Spain, the RD 436/2004 was replaced by the *Royal Decree 661/2007*, which is the legislation currently in force. Other reasons for issuing this updated version were that new knowledge about the system had been attained during the RD 436/2004 period, and that the tariffs needed to be adapted to better reflect the current market.

The basic structure of the system was kept but one modification made is that the hourly market price received by some of the technologies in the special regime, is now limited between a highest and lowest amount. To complement this, a new bonus for every produced kWh is introduced, guaranteeing a sufficient income when the market price is low. The bonus is not given when the market price is high enough to cover the expenditures of the producer. The bonus is thereby a way to avoid the market irrationalities that may arise when new technologies are to compete on markets where the price of oil may decide the electricity price. Another change the RD 661/2007 bring about is that large-scale power plants, >50 MW, that burn biomass or biogas are to receive an extra bonus for helping to fulfil the goals concerning renewable energy production of the RD Law 7/2006.

In the RD 661/2007 the different energy sources included in the special regime are divided into groups, each with an own tariff. Biogas production is included in two of the groups:

- Electricity production in co-generation plants where mainly natural gas or oil are used, but where biogas or biomass are used to some extent, is guaranteed between 7 and 12 eurocents per produced kWh. Smaller plants are given the higher subsidy.
- Electricity production in which solely biogas or biomass are used is guaranteed approximately 13 eurocents per produced kWh, provided that the plant has an installed power of 500 kW or less. Facilities larger than this can sell the produced electricity for approximately 10 eurocents/kWh.

[123] Europe's Energy Portal, 2010b.
[124] National Energy Commission, 2010a.
[125] RES-e Regions, 2010.
[126] National Energy Commission, 2010a.

This tariff is fixed for 15 years, after this it is set to about 7 eurocents per kWh[127]. From the 1^{st} of November 2009 the National Energy Commission is responsible for deciding the tariffs. This institution will also be receiving reports on the amount of power produced in the special regime, assembling this information continuously[128]. In order to be included in the special regime, it is required to present 20 Euros per kW of desired installed effect for all facilities except photovoltaic facilities, where the corresponding requirement is 500 Euros per kW[129].

There is no CO_2 tax in Spain, and there are no plans to impose such a tax according to the economy ministry[130].

The IDAE (The Institute for the Diversification and Saving of Energy) has since 1987 been providing capital for energy saving and efficiency projects and renewable energy projects through *Third-Party Financing*. The process is initiated by an evaluation of the project applied for, the IDAE helps deciding the most appropriate technical solution. If the project is considered feasible the institute will pay the investment or part of the investment, meaning the IDAE owns the equipment. This is, however, only the case until enough incomes are gained, through energy savings or energy production, to cover the expenditures made by the IDAE. Through this, the investment is never a loan from the institute to the final recipient, and the final recipient is therefore never in dept. It also means that the final recipient is unaffected by the depreciation of the plant. As soon as the initial investment is recovered, the IDAE leaves the project. Technical support is supplied during the course of the project until the day the facility is taken over by the final recipient[131].

The IDAE also provide technical advice and financial support through *Project Finance and Provision of services*. As the name reveals, this support means that the developer of the project can use the technical knowledge of the IDAE and also get financing from the institute, this time through a more conventional loan[132].

Subsidies covering part of the investment can be attained from institutions in the different autonomous regions. The size of the subsidy depends on the autonomy, and it may also vary from one year to the next. For example, in Catalonia, the region where most money is invested for this purpose, subsidies covering 20 % of the investment can be attained during 2010 through the ICAEN, the Catalan Energy Institute[133].

3.3.2 Waste management

The Spanish waste management policies are established in the *National integrated plan for residues (PNIR) 2007-2015* in which the waste hierarchy: prevention - reutilisation - recycling - energy recovery - elimination is the advocated way of handling. In the plan is mentioned that inappropriate ways of handling of organic residues may lead to emissions of greenhouse gases, but biogas production as a way to avoid this problem is not mentioned. There is, however, an obligation to make use of the methane produced at the landfilling sites still existing in Spain[134]. In 2008 more than 7 million tonnes of organic waste was disposed of in landfills, and measures will have to be taken in order to reduce this to an amount in accordance with EU targets. The PNIR includes a strategy to reduce the amount

[127] The Ministry of Industry, Tourism and Commerce, 2007.
[128] National Energy Commission, 2010b.
[129] International Energy Agency, 2010b.
[130] Europe's environmental news and information service, 2009.
[131] The Institute for the Diversification and Saving of Energy, 2010b.
[132] The Institute for the Diversification and Saving of Energy, 2010c.
[133] Sarquella, 2010.
[134] The Ministry of Environment, Rural Surroundings and Marine, 2010c.

to 4.2 million tonnes by 2016[135].

Digestion of *Animal residues not intended for human consumption* is allowed when following the rules of the common European policy described in Section 2.2[136].

3.3.3 Agriculture

The agricultural sector contributes to 10.6 % of the emissions of greenhouse gases in Spain, and 90 % of these emissions come from the handling of manure. This coupled with eutrophication problems in areas with a high production of livestock has led to an increased effort to take care of this material, preferably through anaerobic digestion. Using manure as the main substrate is advocated in the *Plan for digestion of manure* issued by the Ministry of Environment, Rural Surroundings and Marine[137].

In certain parts of Spain, Catalonia for instance, the extensive use of pig manure as fertiliser furthermore contaminates the ground water. Since the biogas production does not eliminate the nitrogen in the digestate, the spreading of this as fertiliser may be problematic as limits exist regarding the amount of nitrogen allowed to spread on fields. A post-treatment eliminating nitrogen is possible to install but this may pose a large extra cost[138].

In the end of 2007 a law concerning sustainable rural development was issued in Spain, *Law 45/2007*. In the strategy for the implementation of this law during the years 2010-2014, focus is put on long-term sustainability and also on avoiding urbanisation of the rural areas. Whether a development of the biogas production in the rural environment would directly contrary to this is difficult to know, but the strategy also implies that renewable energy production is one desirable way to achieve rural development. For instance, *Directive 2.2.1* points in this direction: *Generation: Give incentives for the generation of renewable energies in the rural areas, in all cases in a way which respects the environmental values of the territory, including the landscape, and empower the mechanisms of which their implementation bring about an additional value which have direct repercussions on the same rural area of generation,* as do Directive 2.2.2.: *Consumption: Promote the technological change, give incentives to the saving and the self-consumption coming from renewable energy sources (wind, solar, biomass), and to give equal incentives to energy efficiency measures*[139].

Energy crops are not cultivated extensively in Spain, approximately 105,000 tonnes were used as biogas substrate in 2007, consisting of maize, rapeseed, beets and sunflower[140]. The explanation for this may be that, unlike in Germany, no extra bonus is received for the production of energy crops in Spain[141]. The scarcity of water in Spain would also pose a problem for an extensive energy crop production[142].

3.3.4 Barriers for further development

The conditions for biogas production in Spain can be considered good, at least in theory. According to Sarquella[143], at the Catalan Energy Institute in Barcelona, biogas projects would be profitable if they were carried out correctly. If an investment subsidy is obtainable, the produced electricity is sold, an income from gate-fees is obtained and if some of the produced heat can be used (and in this way save otherwise bought energy), a profitability of

[135] The European Compost Network, 2010a.
[136] The Ministry of Environment, Rural Surroundings and Marine, 2010a.
[137] The Ministry of Environment, Rural Surroundings and Marine, 2010b.
[138] Sarquella, 2010.
[139] The Spanish Government, 2010. Translation by author.
[140] Probiogas, 2010.
[141] Gisbert, 2010.
[142] Barz, 2010.
[143] 2010.

around 8 % would be possible[144]. According to Pinzano[145] at the biogas-project planning company *Ecobiogas*, the pay-back time for a biogas installation is around 4 to 5 years[146]. Nevertheless, the development of the sector is limited, not least due to the financial crisis which has been a very hard blow on the Spanish society.

Barriers affecting the production

- **Large initial investments:** There is an interest for biogas projects among farmers, but the large investment needed may act as a barrier for the initiative. Also, the cost of connection to the electricity grid may sometimes be substantial if it is not possible to connect at the point closest to the plant. Depending on the area, the grid may be saturated and the projector may have to pay large sums to reach a point suitable for the connection[147]. According to Pinzano[148], projects have been initiated but stopped solely because of the very large cost (one example of 1 million Euros) of connecting to the suitable point of the electricity grid[149].

- **Problems on the local level:** There is sometimes a tendency of the public objecting to the construction of biogas plants in Spain, as it is a new, unknown technology. Biogas is also associated with incineration of waste and the inconveniences this may entail. For this reason, the decision-makers on the local level are sometimes not entirely positive to biogas production as they do not want to lose their voters. To try to counter this tendency the ICAEN, for instance, arrange meetings to show how plants work and to try to solve the problem through conversation. There is also cooperation with parts of the agricultural department that have similar functions[150]. However, according to Pinzano, the agricultural department is not altogether positive to the biogas development. This because the mixed contents of the digestate makes it more difficult to certify as an adequate fertiliser, compared to manure[151].

- **The financial crisis:** Even though, as mentioned above, the development of renewable energies is promoted as a way to combat the current financial crisis in Spain, the crisis pose one of the largest barriers for the biogas development according to all interviewed. Since hardly any loans are possible to obtain from the banks, the relatively large investment that a biogas installation involve can simply not be made[152].

- **Political instability:** As a result of the crisis, politicians have started to discuss whether the feed-in tariffs could be decreased with a retroactive effect. It is not likely that this will affect the biogas tariff as this is low compared to those of other renewable energies, but the insecurity these political discussions imply is a reason for banks being less willing to provide loans for all types of renewable energy projects[153]. Many photavoltaic projects have already been interrupted as a result of this instability[154].

[144] Sarquella, 2010.
[145] 2010.
[146] Pinzano, 2010.
[147] Sarquella, 2010.
[148] Pinzano, 2010.
[149] Pinzano, 2010.
[150] Sarquella, 2010.
[151] Pinzano, 2010.
[152] Sarquella, 2010.
[153] Sarquella, 2010.
[154] Pinzano, 2010.

- **Competition with other technologies:** The previous (before 2004) low use of cattle manure for biogas production can be explained by competition with the conventionally used technology, in which wet manure is thermally dried through combustion of natural gas[155]. This problem should, however, not pose a threat for the future biogas production as this type of treatment is now prohibited[156]. The use of OFMSW (Organic Fraction of Municipal Solid Waste) encountered the same competition problem - landfilling or aerobic composting were seen as cheaper alternatives in the beginning of the 2000's[157].

- **Problems with bureaucracy and permissions:** Difficulties in obtaining necessary permissions and licenses are also mentioned as a barriers for the development, both by Pinzano and by Gisbert[158] at *Husesolar*, a renewable energy projecting company in Valencia. In Spain several documents of handling are needed to construct a biogas plant for instance: a handling depending on what residue or sub-product is used, a handling to attain building permit, a handling necessary for energy production and an industrial activity handling.

  The latter covers several areas. The application for urban compatibility and the environmental authorisation/license corresponding to this can be problematic to obtain since the nature of the biogas production makes it suitable for rural environments. Rural areas are often regarded as "Rustic terrain" which makes it very difficult to obtain the required approving. It is necessary to justify the connection to the activity of the area, and to clarify that the project only will give small environmental and urban impacts[159]. The handling process can, according to Pinzano, take up to two years which means investors may lose interest in the project during the process. Pinzano also suggests a "catch-22" situation were a way to get out of the crisis would be investments in biogas projects, but that these investments are being held up by the slow administration process[160].

Barriers affecting the utilisation of biogas

- **The digestate is not being used as fertiliser**: As mentioned above, the quality of the digestate is questioned by the agricultural department and also by the farmers to some extent, the habit of using chemical fertilisers is difficult to change as "you know what you get"[161]. There is, however, an ambition to start using the digestate as fertiliser, expressed as a measure to reach the goals of the above mentioned National Renewable Energy Action Plan[162].

- **Difficulties in using the heat produced**: There are examples of the utilisation of the heat produced, for instance for the heating up of greenhouses. However, the very hot weather conditions in Spain during a large part of the year implies a limited incentive to utilise the heat[163]. The utilisation of the heat for district heating is discussed but not yet implemented[164].

[155] The Institute for the Diversification and Saving of Energy, 2005.
[156] Sarquella, 2010.
[157] The Institute for the Diversification and Saving of Energy, 2005.
[158] Gisbert, 2010.
[159] Gisbert, 2010.
[160] Pinzano, 2010.
[161] Pinzano, 2010.
[162] The Ministry of Industry, Tourism and Commerce, 2010.
[163] Pinzano, 2010.
[164] Sarquella, 2010.

4. Comparison of the different national strategies

The previous chapter has presented an overview of the existing biogas systems and of the conditions for biogas production in the chosen countries. The aim of the present chapter is to compare the systems and to highlight and discuss factors which have had significant importance for the development so far, and factors that may influence the future development of the sector.

4.1 Important incentives

In the EU and in all countries investigated, biogas production is clearly stated as a technology of great potential which should be developed in order to obtain a sustainable energy system. Table 4.1 below shows incentives divided into categories, where X indicates that the incentive exists.

Economic support	**SE**	**DE**	**ESP**
Investment subsidies	X	X	X
Favourable loans for the investment		X	X
Feed-in tariff		X	X
Green certificates	X		
Indirect support through taxation of fossil fuels	X	X	
Additional support for small-scale facilities		X	X
Incentive for using manure	X	X	X
Gate-fee income for the handling of waste			X
Incentive for using energy crops		X	
Knowledge	**SE**	**DE**	**ESP**
Support through information	X	X	X
Biogas production - a part of the national rural development plans	X	X	X
Biogas production - a means of handling manure	X	X	X
Additional benefits	**SE**	**DE**	**ESP**
Priority access to the electricity grid		X	X
Priority access to the natural gas grid		X	
Preferential conditions for gas-driven cars	X		
Extensive district heating network	X		

Table 4.1: Existing incentives for the biogas production and utilisation.

However, as was noted in Table 3.1, the factual production differs significantly between the countries - the production of Germany is 35 times larger than that of Sweden, and 18 times larger than the Spanish production. This could be regarded as a strange phenomenon since the geographic distance between the countries is small and as the political systems are relatively similar. The German development is thus a result of very favourable economic incentives - the most advantageous German feed-in tariff for RES-E production can be up to 10 times larger than the price for sold RES-E in Sweden (depending on the market), and almost 3 times larger than the Spanish feed-in tariff.

4.1.1 Economic support

As the installation of a biogas plant imposes a relatively large investment, preferential loans or subsidies covering parts of the initial costs may be of importance for the implementation of projects. In all investigated countries, investment subsidies exist, and favourable loans can be attained in Germany and Spain. A favourable loan or an investment subsidy seems, however, not to be a sufficient incentive for initiating a biogas project. A stable income from the production is necessary to calculate the pay-back time for the project.

The means of production and the means of utilisation chosen by the countries differ significantly, especially the Swedish system can be said to deviate from that of Germany and Spain. As previously mentioned, biogas has in Sweden been regarded as a by-product in the waste management rather than an energy source in itself. This coupled with a low price for electricity, and a general perception that the biogas should be used as biofuel in order to obtain the greatest climate benefit, has formed the current system. In comparison, as fossil fuels are still used to a large extent for the electricity production in both Germany and Spain, biogas is regarded as one of the renewable electricity production options, and for this reason the support measures favour this type of production. Both Spain and Germany have relatively generous feed-in tariffs which have boosted the production of RES-E in general, and primarily PV and wind. In Germany biogas has also developed much, in Spain not at all to the same extent.

Differences in approaches to biogas promotion can be noted. In Sweden, for instance, much effort is put on an extensive strategy for the development, whereas in Germany and in Spain the economic incentives play a larger part of the promotion. There is a discussion regarding the feed-in tariff system used in Germany and Spain. From a strictly socioeconomic point of view some argue that the system is inefficient in that it sometimes promotes production in areas with not the best conditions. However, a new technology such as biogas production (and many other renewable energy technologies) may not be commercially viable without a stable support system - the stability a tariff fixed for 15 or 20 years entails is of great importance. According to Raven et al.[1] new technologies may have problems crossing the “Technological valley of death”, and may need protection through what is known as “Strategic niche management” in order to become established on the market. Instability in policies will be discussed further in the following section 4.2. One may also argue that, as we need to develop the renewable energy sector to such a considerable extent, measures should be taken to promote many types of production and that not only the most economically feasible technique.

In Sweden, Green Certificates are instead attained for the production of RES-E in order to make the production more profitable. Green Certificates can be compared to the feed-in tariff since it is a production-based support-system, but as it is dependent on the market it does not entail the above discussed stability.

Taxation of the use of fossil fuels imposes an indirect competition benefit for fuels exempted from this tax. In Sweden, the energy and CO_2 taxes are regarded as some of the most important support measures, and the taxes are relatively high. A tax does, however,

[1] 2009

not support biogas production per se (if the revenues are not allocated to biogas purposes), rather the renewable energy source being the most competitive on the market. It can thus be regarded as a fairly technology neutral support measure. On the other hand, a tax is an efficient means to achieve a "polluter-pays" system.

The German and the Spanish feed-in tariff favour small-scale farm-based facilities. Small-scale facilities are often not as efficient as larger scale installations - benefits of scale apply to most technologies, not only biogas production. One may thus argue that the German development is socioeconomically inefficient, and that the number of plants constructed is an inappropriate measure of the successful implementation of a biogas system. However, in order to assess whether the system is efficient or not, a more comprehensive analysis is needed. The indirect economic values of created jobs, rural development and avoided climate-change imposed costs should be taken into account, as should the factual production. This lies unfortunately outside the scope of this study why only a qualitative discussion can be made.

The synergic climate benefits of digesting manure are identified in all countries, and support measures for this type of biogas production are either already implemented or are advocated. Utilising manure is either a prerequisite for attaining some types of economic support, or is rewarded by an extra manure-bonus. Digestion of manure will be discussed further in the following section 4.1.2.

In Spain an income can furthermore be attained through a gate-fee for the handling of some types of wastes. This used to be the case in both Sweden and Germany, but with the increased competition for these residues, some wastes are even charged for in the current situation. Also the energy crop production has to be paid for. In Germany there is an extra bonus for energy crop production why this type of cultivation has developed significantly, leading to various environmental problems connected to monocultural cultivation.

4.1.2 Knowledge

In Spain it is the projecting companies, with support from organisations such as the Catalan Energy Institute, who are the actors that initiate projects, whereas in Germany the farmers themselves are very active in the initiation phase. This could be because the farm-based technology is by now well-developed and well-known of in Germany, as opposed to the situation in Spain and in Sweden. Furthermore, according to Gómez-López et al., the implementation of renewable energy technologies can be facilitated if constructors of the needed equipment exist in the region. This can be seen in the wind power dense Spanish region Galicia where many constructing companies are based[2]. As most biogas plant constructing companies are found in Germany, the same reasoning could possibly further explain the German development - the more parties interested in the implementation of the biogas projects, the faster the development should take place.

As many actors are involved in the biogas sector and many conditions need to be fulfilled for the successful implementation of the technology, a separate actor solely coordinating and connecting the involved parties may be necessary. The German Fachverband Biogas is already a big interest group and in Sweden, regional biogas promoting organisations such as Biogas Syd play this role. In Spain there is both the national Probiogas project and also regional actors such as the Catalan Energy Institute. The pretentions of these organisations are good, and their work would probably have a greater effect if certain barriers, discussed below, could be overcome. Once the practical problems are solved, it is promising that there is a base of knowledge and support for aspiring biogas projectors.

[2] Gómez-López et al., 2009.

In all investigated countries, agricultural biogas production is regarded as the sector having the largest potential. The technology is furthermore often seen as a measure to achieve rural development and to handle manure. In Spain this is, however, somewhat ambiguous as the agricultural department is doubtful of the quality of the produced digestate and is, for this reason, hesitant to the biogas development.

4.1.3 Additional benefits

In order to facilitate the connection to the electricity grid, the connection of RES-E installations is given primary access in Germany and Spain. The same rule has recently also started to apply for the connection of biomethane to the natural gas grid in Germany. This means it will always be possible to distribute the produced electricity or biomethane.

In Sweden, "environment cars" receive certain benefits, for instance free parking and exemption from the congestion fee in Stockholm. The previous 1,000 Euro bonus for purchasing an environment car was very effective in that many cars where bought, but the majority of these were ethanol cars. The effectiveness of these incentives for the buying of gas vehicles can thus be discussed. They have probably had a certain effect, but as the energy and CO_2 taxes, this measure can be regarded as fairly technology neutral. The lowered tax imposed on fringe benefits for official gas vehicles, however, has been effective in promoting biogas cars in this sector[3].

It is often difficult to fully utilise the heat from CHP production and for this reason the existence of a district heating network is of interest for the logistics of biogas projects. In Sweden the network is extensive, in Germany it does not exist to a great extent and in Spain it hardly exists at all. As CHP production is the main utilisation of the biogas in the two latter countries, the construction of district heating networks would be very beneficial as the heat produced could be used to a larger extent. Furthermore, both Spain and Germany are more densely populated than Sweden, why it is possible that the network would not have to be very extensive geographically in order to connect the rural heat production and the perhaps urban utilisation of the district heating.

[3]Börjesson, 2010.

4.2 Important barriers

In some cases, the incentives previously discussed exist in the investigated countries, but may not be known of or utilised to their full extent. It may seem as though all needed support is available but, nevertheless, development does not take place. It is thus of greatest importance to take existing barriers into account when discussing the promotion and development of the sector.

Through the investigation certain barriers with a significant impact have been identified. X indicates that the barrier exists, (x) that it exists to some extent but that it is not of significant importance for the continued development. The biomethane market does not exist in Spain, indicated by -.

Economic barriers	**SE**	**DE**	**ESP**
Large investment	X	(x)	X
Lack of long-term perspective in investments	X		(x)
Low profitability for the selling of electricity	X		
Utilisation of heat produced	(x)	(x)	(x)
Limited knowledge about the value of the digestate	X		X
Limited investments due to the financial crisis		(x)	X
Additional cost when connecting to the grid	(x)		X
Logistic difficulties as a result of dispersion of the raw material	X		
Authorities and the public	**SE**	**DE**	**ESP**
Bureaucracy, difficult obtaining permissions	(x)		(x)
Unstable policies and support measures	X		X
Lack of public acceptance of the technology		X	(x)
Upgrading and use of biomethane	**SE**	**DE**	**ESP**
Immature market	X	(x)	-
Upgrading costly	X	X	-
Lack of infrastructure and storage capacity	X		-
Not enough filling stations available	X	X	-
Competition with natural gas	(x)	X	-

Table 4.2: Identified barriers for the biogas production and utilisation.

4.2.1 Economic barriers

Biogas projects can in some ways be regarded as more complicated to implement than other renewable energy solutions. The investment is relatively large, and the plant needs maintenance during the entire operating life-time. At the same time, small-scale biogas production in Germany is similar to for instance PV in the sense that it is often initiated and operated by a private person, in the biogas case, the farmer. That this is possible could be because biogas production in Germany is profitable enough for the private person to dare making the investment. The financing is otherwise repeatedly mentioned as a problem for the implementation of biogas projects in the investigated countries, and there seems to be a lack of long-term perspective when discussing the profitability. As seen in the previous section 4.1.1, investment subsidies and preferential loans often exist, but the initial cost is nevertheless large and may seem daunting to a private investor. The immaturity of the Swedish and the Spanish market means no domestic serial production is taking place, which makes the technology expensive. In Germany, on the other hand, new security requirements have made the initial costs increase why this may be a barrier here also.

Renewable electricity generation is not as promoted in Sweden as it is in the two other investigated countries. The reason for this is the abundance of cheap and, by some considered, clean Swedish electricity consisting of mainly hydro and nuclear power. The need for RES-E production using biogas depends, among other things, on the nuclear power policies. If the nuclear power is to be phased out eventually, substitutes must exist, and it is possible that a developed biogas sector could be part of the solution. However, in the current situation, the price for sold electricity varies according to the market which makes it is difficult to calculate the pay-back time of projects, and thus makes investors hesitant. The Swedish price for sold RES-E, 3-12.5 eurocents/kWh (electricity certificate included), can be compared to the fixed prices for small-scale production in Spain and Germany, 13 eurocents/kWh and up to 30 eurocents/kWh, respectively. If decided that the development of a more small-scale, farm-based biogas production is desirable in Sweden, the limited profitability could pose a problem.

The extra income from selling digestate and/or heat (if CHP production is applied), or the saved expense if these by-products are utilised, is of significant importance for the profitability of biogas projects, not least in Sweden and Spain. It is, moreover, wasteful not to use these by-products why extra care should be taken to, and extra thought should be put into, methods to make use of these benefits. The value of the digestate as fertiliser is, however, often unknown of in Sweden and in Spain, it is in some cases even be regarded with suspicion as discussed previously.

The financial crisis is currently the indisputably largest barrier for the development in Spain, which makes the investigation of other barriers in this country seem rather unimportant in comparison. What can be discussed, however, is the future development once the crisis is over. The development of renewable energy technologies has previously been extremely rapid in Spain. For instance, between the years 2000 and 2004 Spain went from having no production of bio-ethanol to becoming the leading producer in Europe[4]. Whether the same development will take place for the biogas sector remains to be seen.

In some cases in Spain and in Sweden, the connection to the electricity grid may be problematic if the grid operator only allows connection at a site far away from the plant. In Spain there are examples of this issue entailing such costs the entire project becomes unprofitable[5]. It does, however, not seem to be a recurrent problem that poses a significant threat to the development of the biogas sector in the countries. Extra costs due to a dispersion of the raw material is also mentioned as a barrier under certain circumstances in Sweden[6], but neither this problem appear to be of great importance.

4.2.2 Authorities and the public

In Spain, the process of application and authorisation is rather extensive, and may need up to two years. This may make investors lose interest in the projects, and it also slows down the development of the sector[7]. However, as biogas projects are complex in the sense that many factors need to be considered, a comprehensive pre-study can be regarded as necessary[8]. In Sweden the permission process is faster but it may, nevertheless, need up to one year (preparatory work excluded) in certain regions[9]. In Germany 3-6 months are

[4]Gómez-López et al., 2009.
[5]Pinzano, 2010.
[6]Lantz, 2010.
[7]Pinzano, 2010.
[8]Sarquella, 2010.
[9]Lantz, 2010.

usually sufficient but more time may be necessary for the handling process of large plants[10].

As previously mentioned, the stability of policies is of great importance for the development of new, perhaps not yet commercially viable, technologies. In Spain, the recent change in feed-in tariff policies may lead to an instability making investors hesitant and banks unwilling to grant loans. Also in Sweden the biogas policies can be regarded as fairly unstable as the means of support have changed continuously over the recent years. Perhaps it is the problem common for all types of development, that a change in political governance every four years, for instance, makes it very difficult to achieve a stable, long-term set of rules and support measures.

Both in Germany and in Spain, the public opinion of biogas production is rather negative as it is associated with the handling of waste, which in turn is associated with, for instance, bad smell. In Germany the situation has become more problematic with time as a result of accidents and of larger plants bringing about extra traffic. The problem is not yet observed in Sweden, but this might be since the agricultural production is not yet taking place to a significant extent. However, a potential future energy crop cultivation for biogas production in Sweden could face a land-use discussion[11] which will be described in Chapter 5. The importance of the public opinion should not be underestimated - organised public opposition may stop the implementation of projects planned for a long period of time. One example is a biogas project in the South of Sweden, planned for four years, that after much political hesitation was stopped in 2000 due to the pressure from the local public[12]. Lessons can also be learnt from the implementation of other types of renewable energy production. In Sweden, for instance, wind power projects sometimes face severe resistance from the public of the municipality, often by people owning summer houses in the area[13].

4.2.3 Upgrading and use of biomethane

As the upgrading of the produced biogas is a new technology, it is still expensive and in some cases not well-known of. For instance, in Spain biomethane production is regarded as a second step and in the current situation an initiation of the production of "conventional" biogas is the primary aim. In Germany and Sweden on the other hand, biomethane production is advocated but the market is immature and there are still many barriers to overcome before a large-scale implementation is possible. Firstly, economically feasible upgrading is currently only possible at large-scale installations as the technology is costly. For this reason, the biomethane produced is more expensive than natural gas and as a result a competition problem arises. There is, moreover, a lack of infrastructure and fillings stations which can also be regarded as a reflection of the immaturity of the biomethane market.

[10] Holland, 2010.
[11] Ahlm, 2010.
[12] Kahn, 2001.
[13] Börjesson, 2010.

4.3 General conclusions from the case studies

Whether a strategy can be assessed to be successful or not depends on the aims set beforehand and on what type of development is regarded as the preferred. This can be fairly subjective, which is shown by the different strategies chosen by the countries.

- Both the German implementation of the agricultural biogas production and the Swedish development of biogas as vehicle fuel can be regarded as successful. One could thus say that for the development of the *production* of biogas, lessons could be learnt from Germany, whereas Sweden can be regarded as a leading country in terms of the development of the *utilisation* of the gas.
- Lessons should be learnt and transfer of know-how should begin, it can be seen as rather remarkable that this is not already taking place to a significant extent. This may, however, change as German biogas projecting companies are very interested in the Spanish market since biogas production is profitable in the theoretical calculations.
- The feed-in tariff system in Germany has boosted the development of small-scale farm-based facilities. In Sweden, vehicle fuel production is instead the promoted means of utilisation of the biogas.
- The Swedish measures are often of a general and indirect character, for instance the energy and CO_2 taxes and the benefits for environment cars.
- The financial crisis is currently the most important barrier for the development of the biogas sector in Spain.
- Regardless of existing investment subsidies and preferential loans, the substantial initial investment needed for a biogas project may act as a significant barrier.
- There is a very large potential in the digestion of agricultural residues, a fact identified by the EU and by the governments of the investigated countries. The GHG-saving effects of digestion of manure are realised, and biogas production is moreover often regarded as a means to obtain rural development. There is, however, still a suspicion against the use of digestate as fertiliser and a lack of knowledge of the valuable properties of the material.
- The utilisation of the heat obtained from CHP production is often problematic, an extension of district heating networks in Spain and Germany would be one way to solve this problem.
- There are sometimes difficulties with the public opposing the building of biogas plants, why extra care should be taken to planning each project in a way suitable for the local conditions. There is no general way of planning and implementing, each case needs to be handled in a thought-through manner[14].
- The biomethane market is still very immature - the upgrading is expensive and currently only applicable at larger-scale plants.

[14]Kahn, 2004.

5. Discussion

Small scale production vs. large scale production

In order to assess the efficiency of the different biogas strategies, account must be taken to local conditions. One may argue that the biogas should be used where the largest possible net GHG-saving effect is obtained, and that the development should focus on the newest technology and be based on the most recent research findings. This could be important for the general popularity of the technology and also to achieve a resource-efficient system. However, the greatest potential is on the country-side, which makes agricultural biogas production a very interesting topic. The question is whether a large amount of smaller plants is desired or if the focus should be on fewer, large-scale plants. Perhaps both types of plants are needed to make use of the entire potential in the most efficient way. What is clear, however, is that some type of development is necessary in both Sweden and Spain if the ambitious targets described in the previous texts are to be met. For this reason, one can argue that the implementation of smaller-scale projects could be a first step better than standing still.

It is, furthermore, possible that the introduction of small-scale technology would not face as severe problems of acceptance from the public, described in section 4.2.3, as larger scale projects. Svensson et al. makes a comparison to the successful Danish implementation of wind power: *The acceptance and successful development of new technology is facilitated by starting on a smaller scale*[1]*.* The successful implementation of large-scale projects thus depends largely on the manner with which the projects are carried through. More effort needs to be put into avoiding problems small-scale projects may not encounter, such as issues regarding monocultural cultivation and traffic needed for transportation of substrates and digestate. These problems may be solved though intelligent solutions such as a thought-through crop rotations and transportation of material through pipelines to a larger extent. It is possible that larger scale facilities, in combination with small-scale facilities, will be an important part of the future biogas system, but the importance of considering certain "soft values" should not be underestimated.

Biomethane production vs. CHP production

The production of biomethane is generally regarded as the biogas technology having the largest environmental net benefit in Sweden, since biomethane as vehicle fuel would mainly replace petroleum. CHP production using biogas can be compared to the current Swedish CHP production where mainly solid biomass is used. When comparing the use of biomethane and CHP production, the efficiency is furthermore often greater if the gas can be used directly, at least if not all heat produced in the CHP production is utilised. This reasoning explains the Swedish development of biogas as vehicle fuel, as opposed to the development of CHP generation seen in many other European countries. The use of biomethane as fuel

[1] Svensson et al., 2005.

for local bus traffic is of special interest as the distribution logistics are simplified when the geographic area is limited. In the South of Sweden, however, the biogas potential is larger than the need for bus fuel[2], why other means of utilisation could be considered.

As already mentioned, the biogas must be upgraded in order to be used as vehicle fuel, and the upgrading-technology is currently expensive and only profitable when used on a larger scale. There is a risk that potential of small-scale CHP production at remote farms in Sweden is lost if all attention is put on biomethane production. On the other hand, CHP production in remote areas may encounter problems with the utilisation of all heat produced.

One solution for farm-based small-scale biogas production could be the use of what is known as plug-flow technology, see Figure 5.1 from Svensson et al[3]. This type of digestion allows for a drier mix of substrates which may sometimes be of easier access, for instance crop residues. Furthermore, this type of generator in combination with CHP production has been found to be the most economic solution for small-scale applications[4]. Another benefit this technology entails is that less energy is needed for the agitation of the material[5].

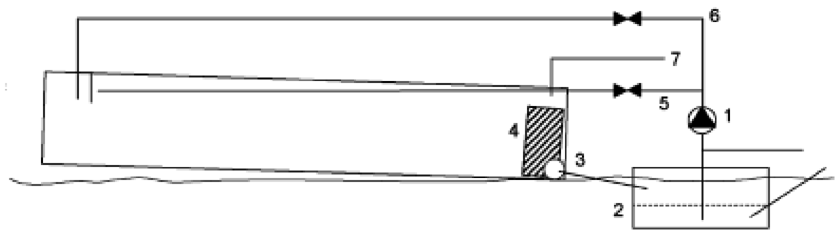

Figure 5.1: Plug-flow reactor.

The best means of utilisation of the biogas thus depends on local conditions, but also on the somewhat abstract view of what type of energy carrier is most efficient and necessary for the sustainable energy system. With the current technology, it is true that biogas used as biofuel in Sweden bring about the greatest environmental benefits[6] and this technology should thus be advocated. There will, however, always be energy losses in the combustion of the biogas, both in a car engine and in a CHP plant. If the heat is utilised in the CHP plant, it is possible that the overall efficiency is greater in this type of production. A possible future development of electrical vehicles could further change the situation, making electricity production turning out to be the most beneficial option. Investments should thus be made in both biomethane production and utilisation - in order to use the currently best technology - and simultaneously in CHP production and in research and development of electrical vehicles. It is also possible that a hybrid car using biogas and electricity is an efficient combination. In this discussion one should, however, not forget that an overall reduction of the amount of cars used is essential. Neither gas-driven nor electrical vehicles will be of importance if the total amount of cars is not reduced considerably and public transport is built out as substitute.

[2]Lantz et al., 2010.
[3]2010.
[4]Svensson et al., 2010.
[5]Boons, 2010.
[6]Börjesson et al., 2010.

The energy-crop (and should be meat) discussion

Co-digestion is found to give a higher biogas yield than digestion of solely one substrate[7]. Currently, experiments are being carried out to find efficient mixes, for instance through the project *Crops 4 Biogas* in Lund, Sweden[8]. What can already be learnt, however, from both literature[9] and the common practise in Germany is that the mixing in of the energy-rich maize-silage in the substrate mix brings about beneficial conditions and high gas yields. It is thus of interest to cultivate maize or other energy crops for biogas production in order to make the technology more efficient. The cultivation must, however, be planned with care in order to avoid the problems the extensive monocultural cultivation has caused in Germany. This is possible; energy-crop production can even bring about synergic benefits for the agricultural businesses if a well thought-out crop rotation is applied. Crop rotation is a measure to maintain the soil fertility, and can also reduce erosion and the amount of herbicides needed for the cultivation[10].

However, energy-crop cultivation has for some years been a heatedly discussed issue. The thought of growing crops for biofuel production instead of growing crops for food production is regarded as controversial when a large part of the world is starving. However, many important factors are often missing in the energy-crop discussion. First of all, starvation catastrophes are often the result of political problems within the affected country in combination with cultivation subsidies in richer countries[11]. The effect of the potential energy-crop production also depends largely on the local conditions and on the way the cultivation is implemented. There is a large difference between the cultivation on marginal lands in for instance Sweden, and the cultivation initiated by foreign companies on soils in developing countries[12]. Every system needs to be evaluated individually with regards to social and ecological sustainability, and it is possible that a future rapid increase in the energy-crop cultivation would affect the global food production in a negative way.

Finally, the discussion is rather simplistic as it is always assumed that the energy-crop cultivation would replace food cultivation. Energy crops could for instance be cultivated on parts of what used to be set-aside land, mentioned in section 2.3. It may even be possible to replace some of the over-produced food with energy crops in order to avoid the problems mentioned that are caused by the over-production. Furthermore, what says energy-crop cultivation could not replace a part of the feed production? In the current situation, 70 % of the total arable area in the world is used for feed production[13] which can be compared with an energy-crop production on 2 % of the arable land[14]. It is thus clear that decreased meat consumption would be very beneficial if a sustainable energy-crop production is desired. Changing to a more vegetarian diet can furthermore be regarded as a relatively easily applicable GHG-saving measure, in comparison to, for instance, changing the whole transportation system to driving on biofuels.

Unlikely as it may seem, a society with a decreased meat consumption could pose a "threat" for the biogas production as it is based on the management of for instance manure and slaughterhouse waste. However, biogas production including these substrates can be applied until the day not enough animal-industry residues can be obtained, distant as it may seem, then energy crops can be cultivated on what used to be feed-production land.

[7] Cavinato, 2010; Weiland, 2009.
[8] Department of Biotechnology, 2008.
[9] Edström et al., 2008.
[10] Germany's Renewable Energy Agency, 2010b.
[11] The Swedish Society for Nature Conservation, 2010.
[12] Börjesson, 2009.
[13] The Swedish Society for Nature Conservation, 2010.
[14] Börjesson, 2009.

The conversion of a dairy/cattle farm to a biogas-producing farm where organic corps are cultivated would even be suitable as the equipment (manure tanks etc.) could be used directly for the biogas production and this way reduce the investment[15].

Sustainable agriculture

As mentioned in Section 2.3, biogas production at ecological farms is a beneficial combination. The value of the digestate as fertiliser can be fully appreciated as chemical fertilisers are not allowed in ecological practises - replacing the commonly used manure with digestate as fertiliser increases the yield.

Ecological farming is, however, often criticised for being inefficient by using the same reasoning as described above - ecological products are luxuries we cannot afford when many are still starving. The same counter-argument can thus be used also in this discussion - there is not a lack of food, the problems are rather caused by policies, inefficient consumption and distribution problems. The following simplified reasoning implies that ecological agriculture could feed the world if all over-production was avoided: ecological cultivation of winter wheat in Sweden is 40 % less efficient than conventional cultivation[16]. At the same time food worth of 4,600 kilocalories per person and day is produced in the world when the amount needed is around 2,000 per person and day[17], around 130 % is thus over-produced. In reality this is of course a very much more complicated equation, but what is clear is that the discussion regarding ecological farming is rather unbalanced.

Furthermore, calculations of productivity seldom take more abstract values into account. One example is the value of biodiversity which is enhanced in ecological farming. Without certain ecosystem services no cultivation - ecological or conventional - would be possible. The sustainability of the current system should thus be evaluated before ecological farming is dismissed as an unrealistic option.

EU legislation or local initiatives

In order for the development of the biogas sector to start for real in Europe, different driving forces are necessary. These initiatives could come from a higher level, for instance through EU directives or legislation, or from the private investors themselves. One may argue that a preferential EU policy would have the greatest impact, but at the same time, the process of developing such a policy would probably take a very long time and it is not certain that measures sufficient for an extensive development would be proposed.

Furthermore, as the conditions for production vary to such an extent in the different Member States and in the different regions, national support measures adapted to the local conditions are needed to complement the possibly more general EU measures.

It is also possible that the development could be initiated on the local level, by people interested in the technology who want to make a personal contribution to a more sustainable energy system. These people must be encouraged to go through with plans, through different means of support.

[15]Svensson et al., 2010.
[16]Statistics Sweden, 2008.
[17]The Swedish Society for Nature Conservation, 2010.

6. Conclusions and recommendations

In the investigated countries and in the EU, the potential and benefits of biogas production are realised and it is advocated in the renewable energy policies, the waste management policies and in the agricultural policies. It is promising that the ambitions are high but the development does not live up to the expectations in all cases. The investigation has highlighted the differences in policies and production of the countries, showing that the German strategy seems to be most efficient for the implementation of biogas projects. Other conclusions possible to draw include:

- There is a risk that potential is lost in the agricultural biogas production of **Sweden** where upgrading is not possible. Ambitions to do more research on small-scale technology are expressed in the biogas strategy, described in Section 3.1, but to develop the farm-based production, it is likely that larger economic incentives for CHP production are needed. A stable income from the selling of the produced electricity would provide such a driver, which has been seen in Germany. The high feed-in tariffs are, however, argued to be socioeconomically inefficient, by sometimes not favouring the most efficient technology or giving an incentive to use the heat produced. It is, nevertheless, a very effective support measure for the development of new technologies. The German strategy has, moreover, developed for many years, arriving at a system which seems to be working. An alternative to a feed-in tariff could be a climate-compensation for the management of manure, an income of 22 Euros/tonne of manure would, according to Edström et al., make farm-based CHP production profitable in Sweden[1].
- In **Germany**, there is a growing interest for biomethane production. It may be possible to convert the CHP production to biomethane production at some of the larger agricultural plants. As the natural-gas infrastructure is already in place, there will be no distribution problem as long as the grid owners accept the biogas. Substituting natural gas would furthermore be an efficient and direct GHG-saving measure. Changing the feed-in tariffs to supporting biomethane production to a larger extent than currently would probably automatically increase the production, but it is possible that an investment subsidy for the upgrading equipment is also needed. Further incentives for using upgraded biogas produced in close connection to villages for the local public transport would also be a good way to start the implementation.
- The financial situation in **Spain** is currently rather disheartening, making it difficult to predict a development of the biogas sector in a foreseeable future. Once the crisis is over, however, there is a great potential for the technology, which is realised by many smaller RES-E projecting companies and by most authorities. As many German companies are interested in cooperation with Spanish developers, transfer of know-how will hopefully take place automatically. A development of the domestic market

[1] Edström et al., 2008.

would also be desirable in order to press the prices. Simplifying and speeding up the permission process would facilitate the development, it is however possible that this will happen once the technology is established and routines for the process are in place. As can be noted in Table 3.1, there is a relatively large amount of biogas recovered from landfills in Spain, almost 2 TWh. It is possible that upgrading in connection to the landfill sites would be suitable in some cases. Biomethane producers may, however, encounter difficulties since gas-grid operators may be unwilling to let the upgraded biogas connect to the grid[2].

- A versatile set of policy support measures is necessary for the continued development of the biogas sector. This since the production and utilisation can be of such different forms, and whether a project will be successful or not depends on many factors - consideration of local conditions is essential in all individual projects. It is difficult to recommend that solely one technology should be premiered as investments in one single technique in the past, at the time regarded as the best one, has showed that this might backfire once new research is done. What we may be certain of, however, is that the biogas sector is one of great potential, why investments in both the current technology and in research and development should be made.

- The EU could play an important part in the development if it could be a coordinating actor providing a common goal and transfer of know-how across the borders. However, as mentioned above, the measures needed depend on the local conditions why the national and regional institutions should be able to decide the desired type of development. Local initiatives may also speed up the process. The same reasoning can be applied for the discussion of how to overcome barriers. For instance, on the EU level the problem of suspicion towards the quality of the digestate could be solved through a common labelling. On the other hand, problems with the public opposing the technology, for instance, will probably have to be solved on the local level.

Biogas production is a flexible technology which can be adapted to the available residues or energy crops of the future. To not start the development now is a waste of time. Biogas production can, however, by no means substitute the current use of fossil fuels but it has, nevertheless, great potential for being part of a sustainable solution in combination with other renewable-energy technologies, energy-efficiency measures and a reduction of the current use of energy.

[2] Pinzano, 2010.

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8. Appendix: The Interviews

Issues discussed

- System of support?
- Possible gain? Euros/produced kWh? Euros/m^3 gas?
- Cost of biogas production? Euros/installed power? Euros/m^3 reactor?
- Cost depending on substrate?
- Profitability?
- Existing substrates?
- Substrates used?
- Size of the plants in general?
- Means of utilisation of the gas?
- Is biogas used as biofuel at all?
- View of the public on biogas production?
- View of the farmers on biogas production?
- View of the energy companies on biogas production?
- View of the policy makers on biogas production?
- What barriers exist for the continued development of the sector? (see separate tables)
- What actor is initiating and driving the development of the biogas sector? The "Spider in the web" who connects producers, distributors and users? Energy companies, waste management companies, the state or other actors? Or is this actor missing?

Identified barriers for the biogas production and utilisation in the investigated countries

Barriers for the biogas production in general	**SE**	**DE**	**ESP**
Competing means of treatment of substrates	(x)		
Limited knowledge about the value of the digestate	X		X
Higher profitability for crops not intended for biogas production	(x)	(x)	-
Large investment	X	(x)	X
Low profitability for the selling of electricity	X		
Immature market			
Lack of infrastructure			(x)
Lack of public acceptance of the technology		X	(x)
Additional cost due to necessary pretreatment	(x)		
Additional cost in the handling of substrates			(x)
Limited investments due to the financial crisis		(x)	X
Unstable policies and support measures	X		X
Bureaucracy, difficult obtaining permissions	(x)		(x)
Lack of long-term perspective in investments	X		(x)
Lack of technology adequate for the local conditions			
Logistic difficulties as a result of dispersion of the raw material	X		
Different conditions for prod. in different districts/autonomies			
Missing "spider in the web"			
Barriers for the CHP production and utilisation	**SE**	**DE**	**ESP**
Additional cost when connecting to the grid	(x)		X
Utilisation of heat produced	(x)	(x)	(x)
Barriers for the biomethane production and utilisation	**SE**	**DE**	**ESP**
Competition with natural gas	(x)	X	-
Upgrading costly	X	X	-
Immature market	X	(x)	-
Lack of infrastructure and storage capacity	X		-
Not enough filling stations available	X	X	-
No market for gas-driven cars	(x)		-

Table 8.1: Identified barriers for the biogas production.