Socioeconomic impacts from the implementation of biogas production in Bulgaria

Master thesis

Aalborg University

Department of Development and Planning

M.Sc. Sustainable Energy Planning and Management

Author: Todor Stoyanov

August 2013

Aalborg University

M.Sc. (Eng.) in Sustainable Energy Planning and Management, 4th Semester

Project title

"Socioeconomic impacts from the implementation of the potential for biogas production in Bulgaria"

Project period

February 2013 to August 2013

Author

Todor Stoyanov

Supervisor

Poul Østergaard

Pages

57

Abstract

The study looks upon the socioeconomic consequences from the implementation of biogas on large scale and its utilization for electricity and heat production in Bulgaria.

The constantly increasing environmental problems caused by the energy production, the strong dependency on the import of fuels together with current problems with treatment of biodegradable waste open an opportunity for Bulgaria to consider the potential implementation of energy technology which uses locally based resource such as biogas.

The project has two major goals. The first one is to estimate the major biomass resources for biogas production in the country and to define the energy content of the assumed realizable part of them. Second goal of the report is to assess the influence of the implementation of biogas in Bulgaria in the regard to above listed problems.

Preface

The report is graduating thesis of the Master programme "Sustainable Energy Planning and Management" at the Department of Development and Planning at Aalborg University, Denmark. The report was written in the period between February 2013 and August 2013 under the supervision of Poul Østergaard.

The used method for references is Chicago 16^{th} edition.

The Excel spreadsheets used for the calculations are attached in the CD in the back cover of the report.

The author would like to thank to Poul Østergaard for the close supervision and also to Jens Bo Holm-Nielsen an associate Professor at the Faculty of Engineering and Science Department of Energy Technology at Esbjerg Denmark for the provided knowledge in the field of biogas.

Abbreviations and acronyms

GDP – Gross Domestic Product

PPS – Purchasing Power Standard

RES – Renewable Energy Sources

SEDA – Sustainable Energy Development Agency

CHP – Cogeneration Heat and Power

AD – Anaerobic Digestion

GVA – Gross Value Added

CH_4 - Methane

CO_2 - Carbon dioxide

H_2S - Hydrogen sulfide

H_2 - Hydrogen

NH_3 - Ammonia

CO - Carbon monoxide

N_2 - Nitrogen

O_2 - Oxygen

PEMFC - Polymer Electrolyte Membrane Fuel Cell

PAFC - Phosphoric Acid Fuel Cell

MCFC - Molten Carbonate Fuel Cell

SOFC - Solid Oxide Fuel Cell

BTTP - Block Type Thermal Plant

CCHP – Centralized combined heat and power

NG – Natural gas

NOx – Nitrogen oxide

SO_2 - Sulfur dioxide

DM – Dry matter

VS – Volatile solid

NSI – National statistical institute

EAIC – Equivalent annualized investment costs

EAC – Equivalent annualized costs

R - Discount rate

T – Time period

GDV – Gross domestic value

Units used

Mtoe – Million tonnes oil equivalent

Ktoe – Kilo tons of oil equivalent

TWh – Terawatt hours

MWh – Megawatt hours

KWh – Kilowatt hours

MW – Mega watts

GWh – Giga Watt hours

GJ – Giga joules

PJ – Peta joules

Mt – Million tonnes

MCM – Million cubic meters

Nm^3 - Normal cubic meter

m^3 - cubic meter

Contents

1. Introduction

The year of 2007 is going to remain in the history of Bulgaria as a crucial due to the country's entry of the EU. Thus 2007 can be considered as a year which in the picture of the regular Bulgarian supposed to mark the end of almost 20 years of a painful and obscure "transition period". The majority of the population was full with an enthusiasm for the forthcoming numerous opportunities for welfare's improvements and in general about the brighter future which eventually the EU membership would secure.

Despite of its EU membership, some of the macroeconomic indicators of Bulgaria haven't changed significantly in the progressive direction between 2007 and 2013 and the country has remained the poorest in the EU. The GDP index per capita in PPS in 2011 is 46 which is the lowest in the EU (EU27 = 100)(Eurostat 2012).The unemployment rate for 2012 is 12.4% which is higher than the average for the EU27 and corresponds to about 410 000 people. The rate of unemployment has doubled between 2008 and 2012 and the rate of the youth unemployment hit 40% in the beginning of 2013 (National Statistical Institute 2013). Together with the macroeconomic indicators there are severe demographic problems in Bulgaria, one of which is the depopulation of rural areas for which major reason for is considered the lack of economic activities, consequently the lack of jobs for the working age population (Ministry of Labour and Social Policy 2011).

In February 2013, the continuous mass protests against high electricity bills and overall indigence have brought down the government and have led consequently to the first political crisis since 1997. The protest have shown and proved the sensitivity of the society to the changes of the affordability and the access to energy in its variety of utilized forms.

Since Bulgaria has become a full member of EU it also shares pan EU political goals. In the field of energy the common goals till 2020 are achieving 20% RES in the final energy consumption of the member countries, 20% reduction of GHG emissions to the levels from 1990, increasing energy efficiency with 20% by decreasing primary and final energy consumption and 10% share of RES in transport sector(European parliament 2009). Those targets were based on the arising problem with global warming, the aim to decrease the dependency of imported fossil fuels of EU countries, support economic growth and create employment (Ministry of Economy,Energy and Tourism).

Bulgaria set a little lower target of 16% RES in its final energy consumption by 2020. For 2010 the share of RES in the final energy consumption of Bulgaria was 13.8%, while their share in final electricity consumption was 15.1%(Ministry of Economy,Energy and Tourism 2012). The above mentioned target is going be accomplished by the implementation of variety of technologies. The most significant role so far has so called "old" renewable energy source - hydropower contributing with 67% of the total shares of RES (Table1). Hydropower is followed by wind power with 20% and PV's with 12%. The less impact on the electricity production has the electricity generation from biomass utilization with less than 1%. The insignificant role of biomass is notable together with the absence of biogas as a potential technology for electricity and heat production. In fact in Bulgaria there are two biogas plants in operation according to Bulgarian Sustainable Energy Development Agency which operate using sewage sludge and have total installed capacity of 3 MW.(Stoyanov 2013).

Type of RES	[GWh/a]	Share of different sources RES
Wind	1213.5	20%
Hydro	3978.3	67%
PV	735.3	12%
Biomass	26.9	0.5%
Total generation	**5954.1**	100%

Table1. Annual electricity production and shares of different RE technologies (2012).(Sustainable Energy Development Agency (SEDA) 2013)

According to the "Energy strategy of Bulgaria by 2020" the increasing implementation of RES aims also to decrease the energy dependency of the country on the import of fuels. Bulgaria is highly dependent on the imports in order to cover its total energy demand, about 76%(including the share of imported nuclear fuel) in total (Ministry of Economy,Energy and Tourism). Oil and natural gas are almost 100% imported. The nuclear fuel is also imported and only from Russia, although it is considered as indigenous energy source by Eurostat (Ministry of Economy,Energy and Tourism). Excluding the nuclear fuel the dependency on fuel import of Bulgaria in 2010 is 40.3% (Commission 2012). The potential use of biogas as energy resource to decrease the energy dependency on the import of fuels is not considered in the above mentioned strategy.

Apart from the targets related to energy sector-increasing RES in final energy consumption to 16%, reduce GHG emissions with 20% and increase energy efficiency with 20%, there is target for Bulgaria to lower the landfill of biodegradable waste to 35% of the total quantity from 1995 till 2020. The target is implemented in Bulgarian Law for Waste Management and transposed from Council Directive – Landfill of waste 1999/31/EC. Amongst the measures for decreasing the quantities of landfill waste is Anaerobic Digestion (AD) and respectively biogas production. (Ministry of Water and Environment 2010)

Base year 1995	Target (base 100%)	Allowable for landfill(1995 – 2 247 500 t)	Generated quantity landfill waste
2010	75%	1 685 625 t	1 608 340 t
2013	50%	1 123 750 t	1 599 811 t
2020	35%	786 625 t	1 614 839 t

Table2.The allowable generated quantities of biodegradable waste for landfill and estimated quantities till 2020.(Ministry of Water and Environment 2010)

The generated biodegradable waste for landfill in 2010 was 1 608 340 t which is with about 77 000 t less than the allowable quantity (Table2.). For 2013 the predicted generated quantity is 1 599 811 t which is going to be over the allowable target with about 476 000 t. The predicted quantity of generated landfill waste in 2020 is 1 614 839 t which is about 828 000 t more than the admissible 786 625 t. The significant difference in 2020 will oblige Bulgaria to treat biodegradable waste of 828 000 t. (Ministry of Water and Environment 2010). Although AD is mentioned in the "National strategic plan for phased decrease of biodegradable disposed waste" as one of the ways to decrease the landfill of biodegradable waste it is not mentioned where and when is planned an implementation of specific projects related to biogas production.

There is lack of integrated approach which to put the focus on the different socioeconomic impacts from biogas production and utilization in the country. While in Bulgaria there are only two plants in operation in many European countries biogas technology is well implemented and contributes to the achievement of various energy, and environmental goals. In Europe, Germany is the leader with a production share of 61%, followed by UK, Italy, France and Netherlands (RES 2012). Biogas industry is developing rapidly in the EU, between 2009 and 2010 the energy generation from biogas rose with 21% and is estimated to around 127 TWh/a. In the future biogas could have a substantial role by contributing with about 25% of the total bioenergy production in Europe (Holm-Nielsen, Al Seadi, and Oleskowicz-Popiel , 5478-5484).

The focus over certain socio-economic effects of biogas production and utilization in Bulgaria would give a basic idea about its significance to contribute to the achievement of politically set goals which purpose is the solution of a specific energy, environmental or economic problems. Furthermore, defining biogas importance in the socio-economic context could lead to an increase in the rate of its implementation in Bulgaria by creating the appropriate institutional conditions.

Therefore the following research question is addressed:

Is the implementation of the potential for biogas production and its utilization in CHP socioeconomically feasible for Bulgaria?

A prior step to answer the main research question is the estimation of the potential for biogas production in Bulgaria. Therefore the following secondary research question is defined:

What are the main biomass resources and what is their potential for biogas production in Bulgaria?

1.1 Report structure

The structure of the report is presented in Figure 1. Chapter 1 provides an introduction to the current political goals related to the RES. It also gives an idea about the current biogas development in Bulgaria and introduces the research questions. Chapter 2 describes the methods and approaches used in the study. The aim of Chapter 3 is to identify the potential for biogas production from the currently available biomasses in Bulgaria. Chapter 4 presents a socioeconomic feasibility study which focuses over certain consequences from the implementation of biogas technology and its utilization for electricity and heat production in Bulgaria. Chapter 5 discusses the assumptions made in the study and also delimitations which determines the presented results in Chapter 3 and 4. Chapter 5 outlines the findings made throughout the report by providing answers to the research questions and shape the future perspectives in the context of biogas development in Bulgaria.

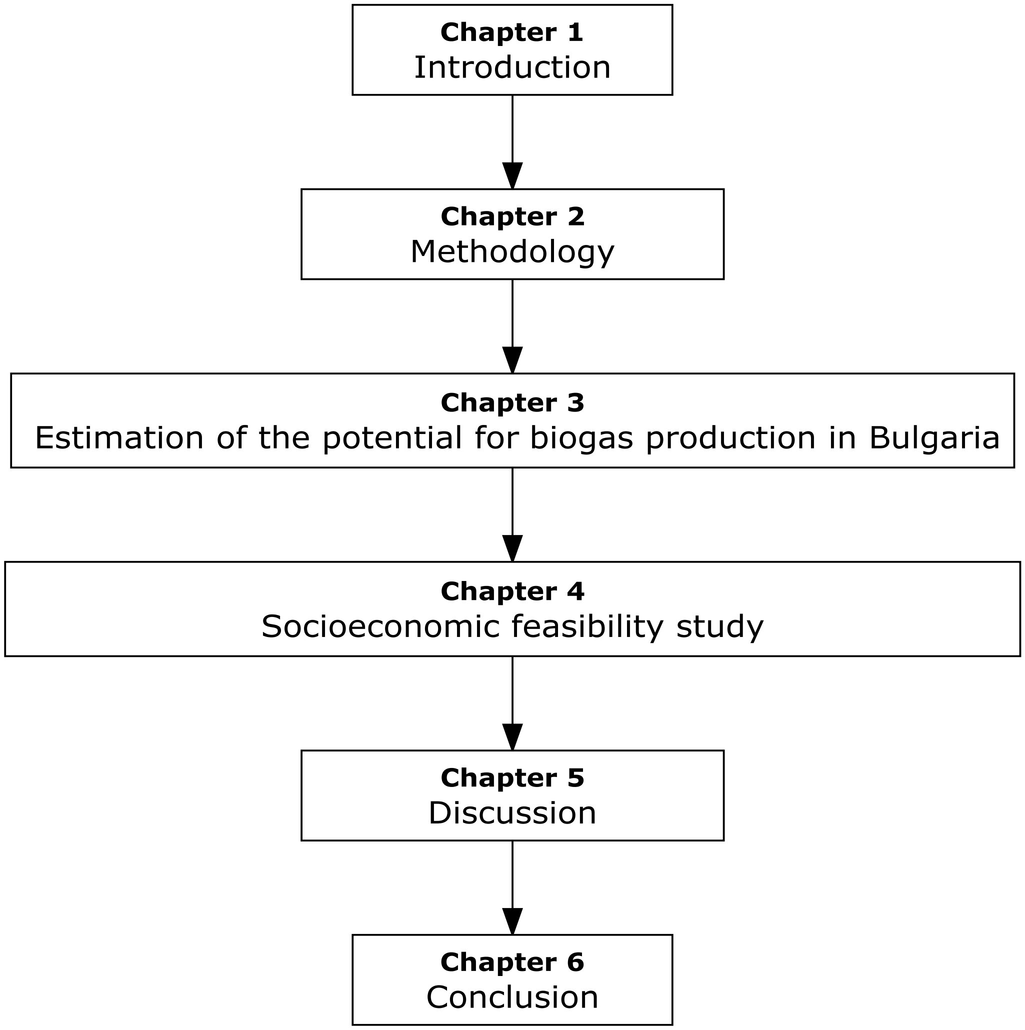


Figure 1. Report structure.

2. Methodology

2.1. Estimation of biomass potential for biogas production in Bulgaria

In order the energy potential for biogas production in Bulgaria to be defined an assessment of the amount of biomasses is made. The biomasses are separated in three main groups, waste, agricultural byproducts and energy crops. As a first step an estimation of the resources is started with quantification of the present total amount of available biomass. The main data input biomass amounts is based on the figures from Bulgarian NSI (National Statistical Institute) and the ''Annual report about the current condition and development of the agricultural sector in Bulgaria".

Consequently, the DM (dry matter) content is determined from which the amount of the potential biogas is calculated. In some cases due to the lack of data to define the biogas yields from different biomasses are used figures from forgoing studies.

The second step consists of approximation of the availability of the different biomasses for biogas production. The approximation considers the potential use of the different biomasses for other purposes apart from their potential use in AD. It is also taken into account their geographical location in the cases an appropriate data is available. Finally the assumed energy potential is defined in order to be used as a basis for subsequent socioeconomic feasibility study.

2.2. Socioeconomic feasibility study

The main goal of the feasibility study is to provide a comprehensive assessment of given alternatives in order to facilitate the decision making process, thus the best one to be delineated and a particular problem to be resolved. There are two types of feasibility studies - socioeconomic and business economic. Both are used for the evaluation of projects' viability. The major distinction between them is that socioeconomic feasibility study is focused upon the consequences of the project's implementation over the society whilst business economic feasibility study considers the project from business economic perspective.(Kørnøv 2007)

The initial step for the design of the present socioeconomic feasibility study is to define the main purpose of the study (Fig.1).

The design of the feasibility study continues with the definition of organizational goals or the objectives of the study (Hvelplund 1998). The objectives are also established as criteria for the evaluation of the feasibility study through use of certain methods as it is seen on Figure 1. The clarification of the organizational goals to large extent outlines the basic preconditions for the study which consequently have a direct influence over the results.

The set of the alternatives is the following step in the design of the study. The three alternatives are set in accordance to be comparable assuming the input and the output of energy are identical (Lund 2010). The input is the energy potential which is based on the assumed realizable potential for biogas production in Bulgaria whilst the energy output is considered to be electricity and heat production using CHP technology. When we deal with the implementation of a certain technology and the production of electricity and heat then the set of the alternatives is influenced by a certain constraints related either to the technology and electricity and heat sectors in the context of Bulgarian energy system. The utilization of biogas for in CHP plants is only one of the potential technologies thus various technologies for biogas utilization are briefly discussed.

For the evaluation of the alternatives are used quantitative methods comparing the costs for the Bulgarian society for implementing every each of the three proposed alternatives in the context of the initially defined organizational goals (Fig.1).

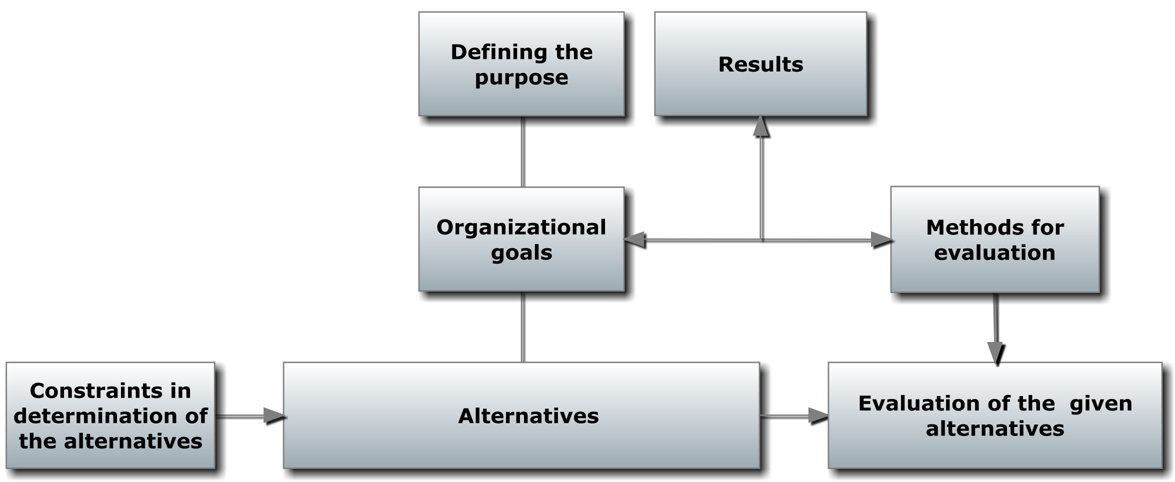


Figure 1. Simplified flow of the socioeconomic feasibility study.(Hvelplund 1998)

Costs for the Bulgarian society are considered from the import share of investment and O&M costs. In the cases when there is an import of fuel for energy production its import share is also considered as a cost for the Bulgarian society. All the data concerning the different technologies used for the three alternatives is shared from "Technology data for energy plants" (Agency and Energinet 2010).

The socioeconomic research takes into account not only the traditional for cost benefit analysis investment and O&M costs but also the external costs. The consideration of the external costs also aims to display the socioeconomic impacts from the energy production of the three alternatives. External costs are monetized in order their impact over the cost benefit analysis to be considered in the context of all the rest monetized costs. For the calculation of the external costs are taken the ones from ExternE project. (Commission 2003)

ExternE project distinguish between four main groups of impacts – human health, loss of biodiversity, materials and crops. The figure used in the calculations of the impacts are based on the average value for the all the external costs presented from ExternE model for the period between 2010 and 2030 for Bulgaria.

Apart from all the considered costs for the Bulgarian society the author includes the potential benefits from biogas production and utilization (Table1.). The benefits from the electricity and heat production are not reflected. The benefits are divided over the three main impact categories agriculture, waste and environment (Table1).

	Monetized benefits from biogas production
Agriculture	Storage savings from manure
	Transport savings in agriculture
	Value of improved fertilizer
	Value of the reduced obnoxious smells
Waste	Savings related to the organic waste treatment
Environment	Value of the GHG reduction
	Value of reduced N-eutrophication from liquid manure
	Value of reduced N-eutrophication from spreading organic waste

Table 1. The monetized benefits from biogas production considered in the calculations.(Nielsen and K. Hjort-Gregersen 2002)

Although, usually a longer lifespan is used for socioeconomic feasibility studies (Hvelplund 1998). The current study uses the technology life time as a time reference.

The comparison of the costs for the Bulgarian society for the three alternatives is made by using the method EAC (Equivalent annualized costs). The EAC method is equivalent to the method of NPV(Net present value) but is preferred method when there is a different lifetime of assets. The EAC is defined by the sum of the EAIC(Equivalent annualized investment costs), O&M costs, fuel costs , the monetized benefits are subtracted. The figures for the costs for the Bulgarian society are defined by taking into account the import share of all the costs.

1. EAC= EAIC + O&M costs + Fuel costs – Monetized externalities;

2. EAIC= Investment costs*r/1-(1+r) ^{t}

   r- Discount rate
   t- Lifespan

The discount rate is of 3% is applied as it is suggested by the Danish Energy Agency for socioeconomic feasibility studies.

The evaluation of the alternatives is focus also on the employment as another socioeconomic impact. The employment is calculated in using two methods in the cases with the employment from biogas plants. The first method is based on the domestic share of the investment and O&M costs, displaying the number of people employed and consequently the man years (Hvelplund 1998). The second method is used only for the alternatives which considers the biogas employment it is based on the employed people by MW installed capacity (Lovrenchec).

The last focus for the evaluation of the three alternatives is dealing with their impacts on the environment and in specific the reduction of the GHG . The comparison is made comparing the emissions from the different fuels used in the alternative proposals with the one emitted from coal based centralized power plants.

2.3 Sensitivity analysis

In order to be seen what would be the change of the costs for the Bulgarian society a sensitivity analysis is made by changing the import share of the investment cost. This is related to the assumption that Bulgarian industry under certain appropriate conditions could have the potential to produce parts of the equipment for and thereby increase the GVA and increase the effect of the investments over the employment. The opposite situation is also considered for the sensitivity analysis.

2.4 Literature study

The literature review is used to provide broad but also specific understanding related to the aims of the study. The broad grasp provides the foundations for the consecutive analysis.

Various literature sources from scientific articles to legislative acts, national and international reports are used in order a comprehensive understanding about the following areas to be acquired:

- The current institutional conditions which related to the energy strategy of the country, future national and international energy and environmental goals, renewable energy, economic and demographic development of the country;
- About biomasses and biogas production, providing knowledge about the process of AD, the biogas potential of the different biomasses and also the constraints in defining the availability of the different biomasses;
- About the approaches to conduct socioeconomic feasibility studies related to the implementation of renewable energy and in specific biogas.
- About the important considerations included and respectively excluded from the socioeconomic feasibility studies.

3. Estimation of the potential for biogas production in Bulgaria

The aim of the chapter is to estimate the amount of the major resources and to determine their potential for biogas production in Bulgaria in order energy potential from biogas to be identified.

Biogas can be produced from all type of biomass if it contains carbohydrates, proteins, fats, hemicellulose and even cellulose. Certainly, biogas yield differs significantly according to the amounts of the latter organic substances in the substrate. The amount of a biogas yield is also dependent on the combination of between the different organic materials. Different biomass content have different role in the process of AD, some e.g. have more securing and stabilizing role in the process while others purely are responsible for the quantity of the produced biogas.(Deublein 2008)

Three main groups of biomasses are included in the estimation of biogas potential (Fig1) – 1. Waste which consists of food processing industry waste, household waste and sewage sludge; 2. Agricultural by-products which is formed by animal manure and straw and residues from cereals; 3. Energy crops where maize for silage is considered.

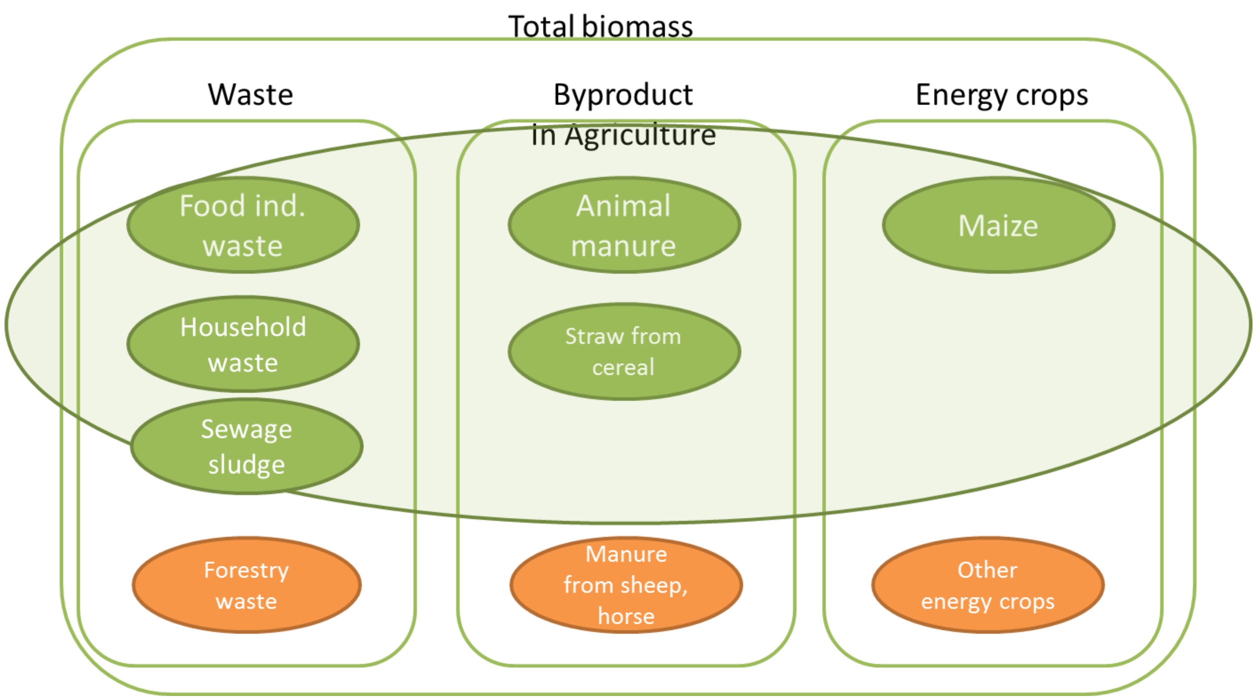


Figure1.The biomasses which are considered and which are not in the present estimation of the biogas.

Waste from forestry might have a great potential for biogas production in Bulgaria considering that 3 749 129 ha or about 37% from the country's territory is covered by forest. However, there is a technological problem with wooden biomass to be used for biogas production due to it's the high lignocellulosic content which requires special pretreatment. The latter is the major reason which obstruct the wide spread use of the forestry waste for biogas production. Another reason is that the use of wood for AD would compete with it potential and much more popular use as a fuel as for instance various ways of burning.

A major reason for the exclusion of the sheep manure is the uncertainty towards its availability due to the situation of the animals in the country is mostly in herds between 1 and 50 animals (Ministry of Food and Agriculture 2011). Another reason which influences the significance of the use of sheep manure and its availability is the fact that sheep in Bulgaria graze between 8 and 9 months of the year. Keeping the livestock in farms with 1 to 10 animals is a main reason which negatively influences the applicability for biogas productions from horse manure thus its potential is not considered in the research.

The importance of all different types of energy crops for biogas extraction should not be underestimated. However, the current research looks upon the general biogas potential from energy crops therefore only one type of plant is decided to be considered as a representative. In order to define the potential for biogas production in Bulgaria from the cultivation of the various energy crops a further research would be required. The reasons why the maize is chosen as an energy crop are presented further down in the chapter.

For calculating the biogas yield from waste category (Fig.1) and maize silage is used the model presented by Charles Banks in "Optimizing anaerobic digestion".(Banks 2009)

3.1 Waste

Waste nowadays is considered as an issue mostly because of the negative impacts over the environment. Major environmental issues are soil or water contamination and also emissions of GHG due to for instance the landfill of biodegradable household waste. In order environmental consequences to be minimized or avoided different treatment for various categories of waste is required. The treatment might lead in some cases to the need additional costs to be made.

AD is one of the methods for biodegradable waste treatment. Through it application the energy content of the biodegradable waste can be extracted in the form of biogas and consequently utilized in the production of electricity and heat in CHP unit.

3.1.2 Food processing industry waste

The annual amount of food processing industry waste in Bulgaria is about 389 000 t (Table1) (National Statistical Institute 2012).

	[Mt]	DM%	Biogas yield-MCM/a
Food processing industry waste	0,389	28%	**23.34**

Table1. Annual biogas potential from food industry waste(Banks 2009)**;** (National Statistical Institute 2012)

The DM content of food industry waste may vary from 20% to 90% which consequently leads to very diverse gas production. The stomach intestine content of cattle has DM content of 14% whereas the DM of the rendered fat or fish oil from fish processing can be even over 90%. However, 28% I assumed as acceptable average dry matter content by Charles Banks (Banks 2009). The potential energy output of this resource equals to 23.34 MCM which is nearly 0.5 PJ.

The use of industrial food waste as a co-substrate for biogas production is widely spread in countries as Denmark. The potential is utilized to the extent that it even requires some of the biogas plants to import industrial food waste from Sweden and Norway.(Jørgensen 2009)

In Bulgaria on the contrary the food industry waste is burden for the food processing companies instead of being considered as a potential source of an additional income. The significant biogas potential of that type of waste and development of biogas production in the country could lead to the launch of a market for it. In addition food processing companies could be considered as important stakeholders in biogas development. AD treatment of the industrial food waste creates opportunities for the companies for instance in cooperation with other industries as farmers or municipalities to invest in biogas plants and therefore not only to solve the problem with handling waste but also achieve additional profits.

3.1.3 Household waste potential

As it was mentioned in the introduction Bulgaria has a target to reduce landfill of waste to 35% of the total generated amount in 1995 by 2020.(Ministry of Water and Environment 2010)

According to authors of the "National strategic plan for gradual reduction of the amount of landfilled biodegradable waste" the predicted amount of household waste which can be treated through AD is 132,000 t in 2020. The latter amount represents about 15% of the waste which is not going to be landfilled, about 0.8 Mt in 2020(Table2). There is not a particular rationale exposed in the plan why and how it is decided that only 15% of the waste not allowable for landfill to be treated in AD process while 470,000 t is predicted to be used in waste incineration plants and 130,000 t waste is forecasted to be composed. (Ministry of Water and Environment 2010) It is not foreseen in the plan the amount of biodegradable waste which can be treated in AD process in 2013, from the waste which is not assumed to be landfilled about 0.5 Mt (Table2). If it is assumed 15% of the amount which cannot be landfilled in 2013 is potentially used in AD then 0.07 Mt would be provided for biogas production.

Biodegradable household waste	[Mt]	DM%	**Biogas yield-MCM/a**
Total generated -2013	1.6	52%	**286.5**
Waste not allowable for landfill -2013	0.5	52%	**85.2**
Total generated waste(predicted) - 2020	1.6	52%	**289.2**
Waste not allowable for landfill (predicted)-2020	0.8	52%	**148.3**
Predicted annual amount for AD treatment -2020	0.1	52%	**23.6**

Table2. Annual biogas potential of biodegradable household waste in Bulgaria. ()

In Table2 are presented the potentials for biogas production from biodegradable household waste based on the total generated and not allowable for landfilling amounts of waste. Potentially usable for biogas production are considered the total amounts of biodegradable waste which theoretically are not foreseen to be landfilled respectively about 0.5 Mt in 2013 which results in 85.2 MCM biogas energy and 0.8 Mt in 2020 and 148.3 MCM.

Although, the potential of biodegradable household waste for AD treatment seems considerable there are many issues experienced other places. For instance Denmark several plants which had used household waste as a co-substrate but some of them stopped because of problems related to the appropriate separation of the waste which had led to inhibition of the AD process. Another issue of the biodegradable household waste which limits its greater utilization experienced in Denmark is the pungent smell.(Jørgensen 2009)

3.1.4 Sewage sludge potential

There are reports which point out that 69.2% of the Bulgarian population (5 079 000) is connected to the public sewage sludge systems. The sewage sludge of nly about 40% (2 034 000) pass through wastewater treatment. The amount of the DM content is 124,200 t/a per two million people. The potential amount of biogas production is 345 m^3/t of DM with methane content 50%. The total biogas production would thus correspond to 42.8 MCM/a which can result in about 0.9 PJ energy yield. The potential of the biogas from sewage sludge is expected to increase with the gradual growth of the number of wastewater treatment plants in the country. The greatest potential is situated in the areas with high population density. Most populated region Bulgaria is South West where the capital Sofia is also located. One of the sewage treatment plants which produce biogas is located in the suburbs of Sofia. (Ministry of Economy,Energy and Tourism 2009)(Ministry of Economy,Energy and Tourism 2009)

Even though sewage sludge can be a useful biomass for biogas production there are technological issues derived from the specifics of the biomass and the way it is collected and treated. Those issues require the technology to produce biogas from sewage sludge to use only sludge which limits the flexibility in the utilization that biomass source.

3.2 Agricultural by-products

By agricultural by-products is meant the waste from agricultural activities. The agricultural by-products are separated to animal manure and crop residues.

3.2.1 Animal manure

Manure and all the animal excreta are considered to have great potential for biogas production. Worldwide animal excreta as a result of animal breeding is considered as major anthropogenic source of methane and consequently a contributor to global warming effect(Abbasi 2012). In total the animal breeding is accounted to 18% of the world's GHG emissions in CO_2 equivalent. Animal production emits

37% of the global anthropogenic methane, 65% of the nitrous oxide and 64% of the ammonia (Holm Nielsen, Oleskowicz-Popiel, and Al Seadi 2007).

In addition the inadequate management of the animal manure and in some cases its raw use as fertilizer can cause water and soil pollution, emit pathogens and ammonia due to the high nitrogen content in the raw manure.(Holm Nielsen, Oleskowicz-Popiel, and Al Seadi 2007)

The treatment of animal manure in AD can mitigate the above mentioned negative effects. It can also decrease the level of substances in the manure which cause the unpleasant odours compared to the conventionally stored manure. A decrease of the smell of about 80% is already experienced (Fig.2),12 hours after the digested slurry is applied the odour is nearly fully gone .(Al Seadi, Rutz, and Janssen 2008)

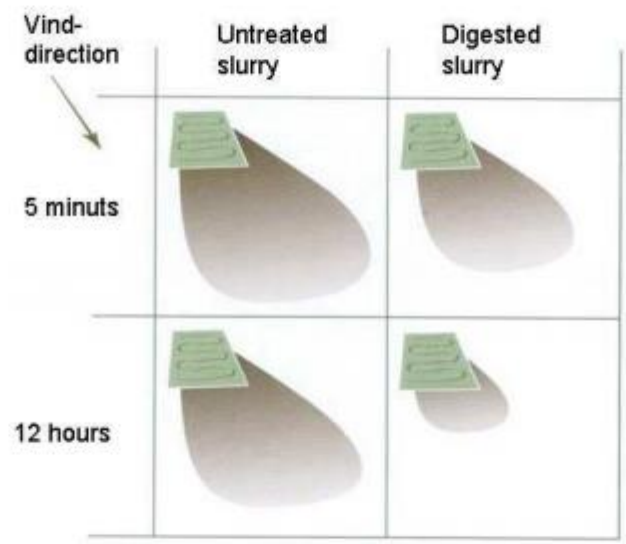


Figure 2. Areas of odour dispersion for digested and untreated slurry (Al Seadi, Rutz, and Janssen 2008)

Utilization of the animal manure in AD have not only environmental impacts but also technological. Animal manure is required for the stabilization of the AD process although it separate use as a substrate won't result in high biogas yields. In order the significance of the animal manure for biogas production to be outlined an example of its utilization in Germany where animal manure is the second most used biomass for biogas production is presented on Figure 3.

Liquid cow manure constitutes 24% of the amount of the total mass of the used substrates in German biogas plants. Second most used animal manure is pig manure with 9%. The solid cow manure has share of only 2%. Less than one percent is the share of solid pig manure, wet poultry manure and dry poultry manure.(Braun and Weiland 2010)

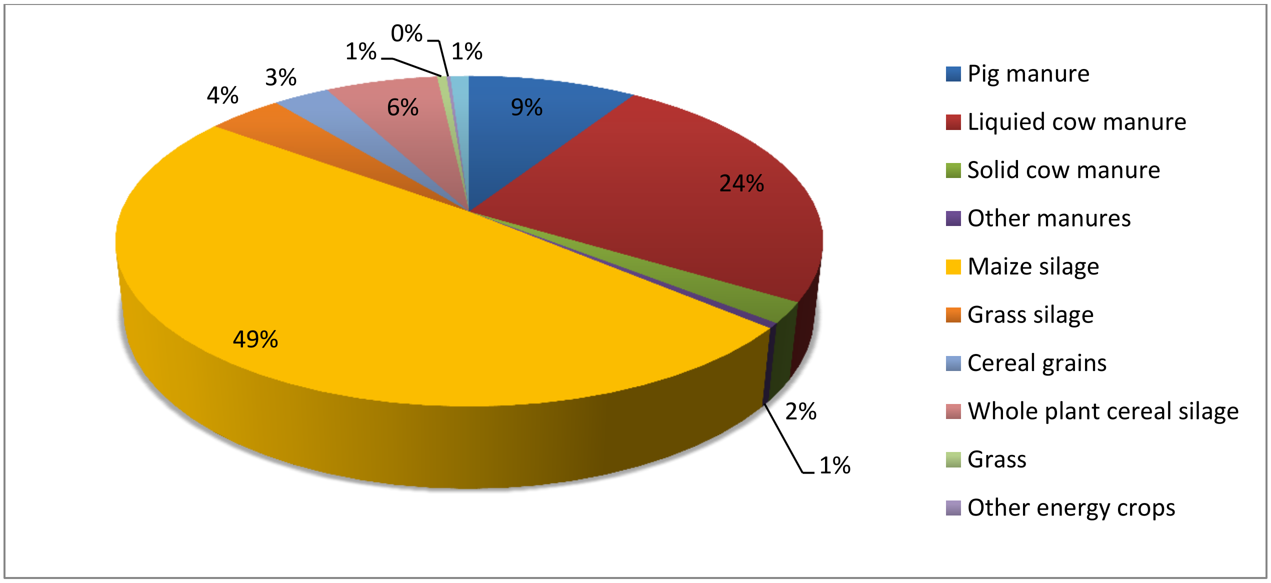


Figure3.*Avarage share of different substrates in German biogas plants (2009)*(Braun and Weiland 2010)***.***

The highest potential for biogas production from animal manure in Bulgaria is from dairy cows with annual 471 MCM (Table3). Way less but still second is the potential from manure of the rest cattle with – 215 MCM/a. Third and fourth come the potential from pigs and hens, respectively with 134 MCM/a and 115 MCM/a. The broilers have three times more potential compared to the sows. If the potential is grouped by type livestock then cattle have highest potential of 686 MCM/a followed by poultry with 169 MCM/a and pigs with 152 MCM/a. In total the biogas potential from animal manure is about 1008 MCM/a which has an energy value of 22.2PJ.

	Animals [1000 heads]	Manure [kg/day]	DM [%]	Manure [t/a]	**Biogas yield MCM/year**
Cattle	227	30.6	12.7	6 946 200	**215.3**
Dairy cows	330	51.0	10.7	16 830 000	**471.2**
Pigs	608	8.8	6.3	5 374 720	**134.4**
Sows	54	17.0	5.0	909 500	**18.2**
Hens	7 604	0.1	63.3	501 864	**114.9**
Broilers	6 263	0.05	48.0	309 524	**53.9**
Total				**30 871 808**	**1 008**

Table3. Annual biogas potential from cattle, pigs and poultry (number of animals is for 2011 a=(Ministry of Food and Agriculture 2011) **; b=**(Olesen and Bedi 2006)

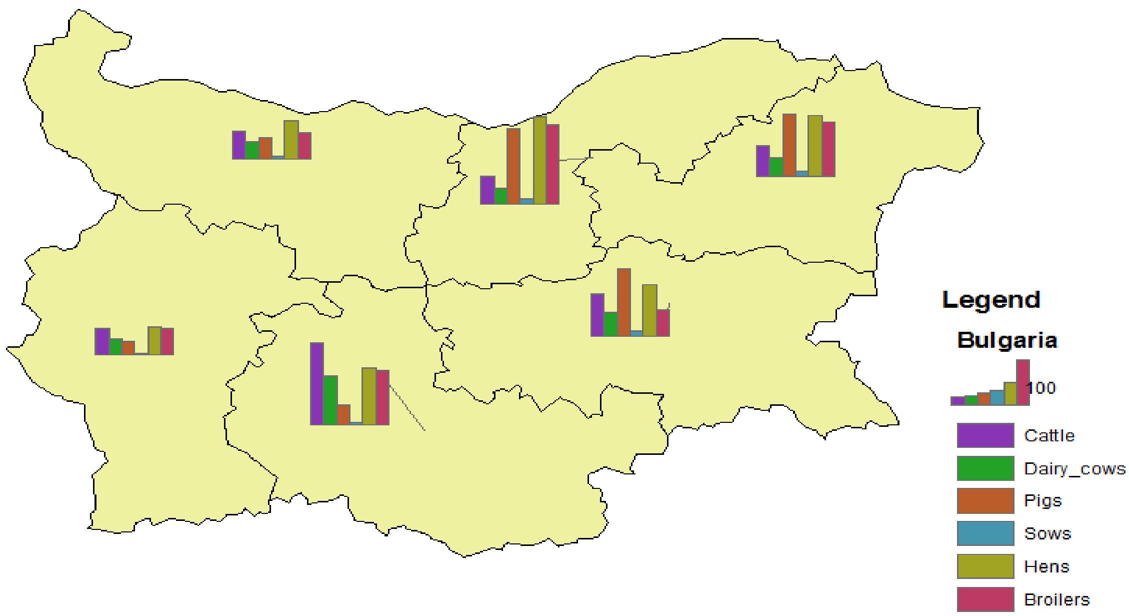


Figure 4. Distribution of animals in Bulgaria (NUTS 2)(2011).

The dairy cows and cattle which provide the biggest biogas potential are mostly situated in South central and South East regions (Fig.4). The regions where most of the pigs are bred are North central, South central and North East. The poultry production is mainly located in North central, North East, and South central regions.

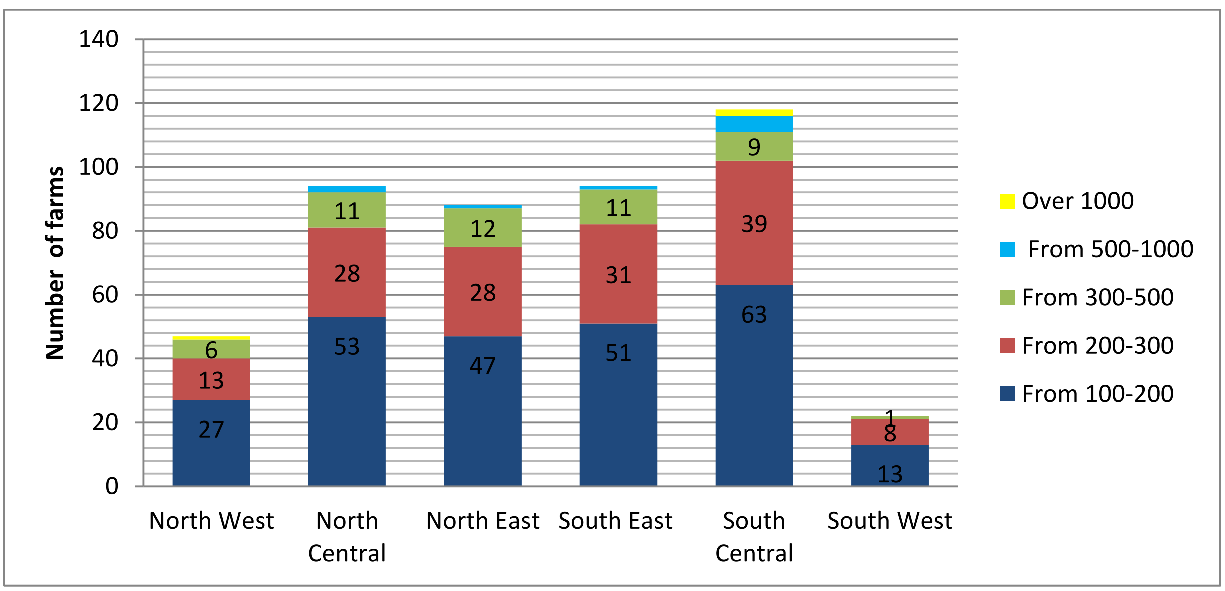


Figure 5. The distribution of dairy farms with more than 100 heads in NUTS 2 of Bulgaria (2011).

Dairy farming has the biggest potential for biogas production 144.5 MCM/a which is almost 50% of the total potential of 471 MCM/a. Biggest impact for biogas production would have the medium and large size of dairy farms with number of heads more than 100. In 2011 in Bulgaria there were 463 dairy farms with more than 100 heads. From them the biggest part of 254 are farms from 100-200 heads, 147 farms from 200-300, 50 farms with 300-500 heads, 9 farms with 500-1000 heads and only 3 farms which breed more than 1000 dairy cows. The greatest number of farms almost 120 is located in the South central region (Fig.5), followed by North central and South East regions with about 95 farms in each. Less than 90 farms with more than 100 animals are situated in the North East region. In the North West there are less than 50 farms while in the South West they are less than half of it.

Although the total potential for biogas from animal manure seems significant its realizable potential is assumed to be be a way less than 1008 MCM/a. A main reason is the availability of the animal manure for the AD. For e.g. In Denmark recently are used only about 4-5% animal manure for biogas production (Jørgensen 2009). There are varieties of factors influencing the availability of the animal manure and assessment of its potential for AD. An important issue might be the exact geographical location of the farms especially of those which breed a large number of animals. These not only have a greater potential for biogas production but in also provide better economic feasibility in the sense of transportation costs of the feedstock. From a business economic point of view it is only profitable to transport the biomass within 15-20 kilometers (Deublein 2008).

A pure technological issue related to the treatment of some of the manure for e.g. poultry manure which has high nitrogen content requires pretreatment which would complicate the technological process and also increase the investment costs, that might also lead to the reduce of the utilization of the animal manure in general.

Another uncertainty specifically related to the cattle is that it is not known the number, location and the period for which the animal herds are grazing. That could reduce significantly the amount of the biogas potential from cattle manure which is the most significant source with about a 70% share of the total 1008 MCM/a (Table3) biogas potential from animal manure. There is also ambiguity about how the animal manure is collected respectively to liquid and solid fractions which influence the amount of the biogas per ton of DM.

Due to the above described uncertainties, 504 MCM/a are considered as realizable which constitute 50% of the total amount 1008MCM/a (Table3). It equals to energy of 11.1 PJ.

3.2.2 Straw from cereals

Cultivated area of land in Bulgaria in 2010 was 3 162 526 ha. The biggest part of it 58% or 1 834 265 ha - was cultivated with cereals. The most cultivated crop is wheat which is cultivated on 1 095 703 ha, second is barley 260 000 ha, followed by oats, rye and triticale.

The annual biogas potential from cereals is presented in (Table 4). This includes wheat, barley, rye and oats straw. About 2 Mt of straw is estimated to be available in Bulgaria for 2010 that could result in 497 MCM biogas and an energy potential of 11 PJ.

The residues from maize cultivation are estimated to be 1.6 Mt/a and the biogas yield from them can result in 653 MCM/a which equals to about 14 PJ. Although the cereals are the most cultivated crops in Bulgaria the straw potential for biogas production is less than the potential from residues from maize production (Table 5.). The reason is that maize residues have almost twice the potential per t/VS than has the straw from cereal.

	[Mt]	DM%	**Total biogas yield-MCM/a**
Straw from cereals	2.0	91.6	**496.7**

Table4. Annual biogas potential from straw from cereals (excluding maize)(Ministry of Food and Agriculture 2011; Banks 2009)

	[Mt]	DM%	**Total biogas yield-MCM/a**
Residues from maize	1.6	0.8	**653.2**

Table5. Annual biogas potential from maize residues. (Ministry of Food and Agriculture 2011; Banks 2009)

According to the “National long-term programme for support of the biomass use” there is only 20% availability for energy use of the straw from cereals and about 60% from the residues of maize production (Ministry of Economy,Energy and Tourism 2009). There are not methods presented on which base the availability of the straw and residue is assessed. The straw from cereals is mostly used for fodder and for bedding in farms, the residues from maize production although not often are used for fodder too. In a near future a competitor for the available straw might be the incineration plants but recently there are not any in Bulgaria which use straw or any other agricultural by-products.

The estimation of the available amounts of straw is complex task considering the lack of data which to display the current use for fodder, considered as it’s a prior use. However, the availability of the straw from cereals and maize residues might be more than 20% and 60% respectively. In case 50% of the straw from cereals is available for biogas production that results in 250 MCM/a biogas. If 80% of the maize residues are considered as an available then there biogas potential is about 520 MCM/a. The two agricultural by-products combined can provide energy of 17 PJ.

There is a large potential for biogas production from straw and maize residues. However the estimation of the available quantity is not the only issue related to their utilization. A major one which causes a serious technological challenge when they are used in AD process is their chemical composition. They have a very large lignocellulosic content which obstruct their degradation in AD process therefore they require a specific pretreatment before entering the digester. These days, because of their lignocellulosic content those biomasses are not preferred and not wide spread for biogas production but with the development of the pretreatment methods and technology they can become a useful co-substrate in AD. Although, there is

3.2.3 Biogas potential from energy crops

Energy crops are already well known and a well utilized feedstock for biogas production in some EU countries. In Germany which is the biggest biogas producer in Europe for e.g. 63% of the total mass of the substrates is a biomass from energy crop production (Fig3). Most popular energy crop used as a feedstock in German biogas plants is maize (Fig.6) harvested for silage production and consequently used as a substrate in the AD process.

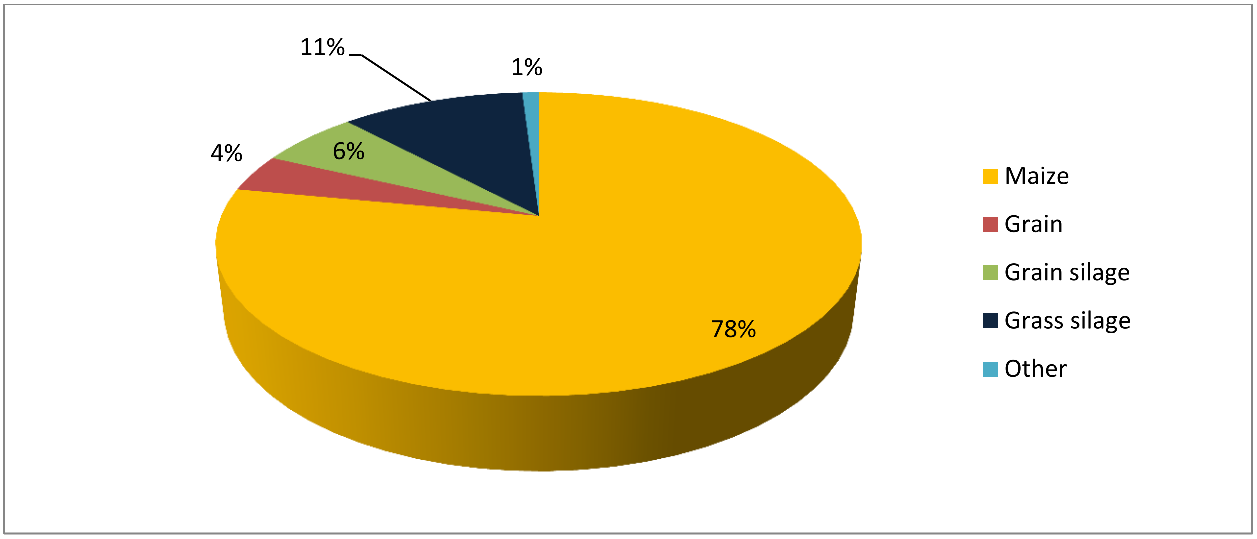


Figure 6. Shares of the different energy crops used as substrates for biogas production in Germany(Federal Environment Agency 2010)

Maize silage has the largest share of 78% from the total mass of substrates followed by grass silage with 11% and silage from cereals with 6%.

A major reason for maize to be so widely utilized as an energy crop in the German biogas plants is mainly because it has one of the highest methane yields 3 573-18 540 m^3/ha (Table 6.). Fodder beets and potatoes also have high biogas yields comparable to maize for silage respectively 3 208-17 000 m^3/ha and 2 593-20 000 m^3/ha. Amongst the cereals highest methane yield possess wheat with methane yield of 1 382-5 005 m^3/ha.

An advantage for the maize silage to be popular as a feedstock for biogas production is also its chemical composition it is reach of sugars easily degradable carbohydrates and proteins which makes it very suitable for AD process (Hutňan et al.).

In addition, maize silage has one of best input/output ratio 5.1 together with fodder beet 4.6 and potatoes 4.8 (Table7). The three of the crops have similar energy demand for digestion but maize has a way less energy requirement for cropping compared to potatoes and slightly less than fodder beet (Table7.). That is a reason for the least total energy requirement which maize has amongst the three crops.

Crop	Crop yield t/ha	Measured methane yield m3/t VS	Methane yield m3/ha
Maize (whole crop)	9-30	397-618	3,573-18,540
Wheat (grain)	3.6-11.75	384-426	1,382-5,005
Oats (grain)	4.1-12.4	250-365	1,025-4,526
Rye grain	2,1	283-492	0,594-1,033
Barley	3.6-4.1	353-658	1,271-2,698
Triticale	3.3-11.9	337-555	1,112-6,604
Sorghum	8-25	295-372	2,360-9,300
Grass	12-14	298-497	3,576-6,538
Sudan grass	10-20	213-303	2,130-6,060
Sun flower	6-8	154-400	0,929-3,200
Oil seed rape	2.5-7.8	240-340	0,600-2,652
Potatoes	10.7-50	276-400	2,593-20,000
Sugar beet	3-16	236-381	0,708-6,096
Fodder beet	8-34	401-500	3,208-17,000

Table6.Energy crops and methane yields per ha.(Braun and Weiland 2010)

Potatoes and fodder beet require special pretreatment because of the soil and sand contaminants which can affect the AD process by inhibiting primary digester and decrease the biogas production by prolonging the hydraulic retention time (HRT). That pretreatment can be considered as disadvantage because it requires special equipment which leads to additional costs.

	Maize	Potatoes	Fodder beet	Rye
Methane yield m^3/ha	9,886	10,258	9,451	814
MJ/ha	353,919	367,236	338,311	29,141
Process energy demand for digestion	-53,088	-55,085	-50,746	-4371
Energy requirement in croping	-16,801	-24,201	-20,351	-16,801
Total energy requirement	-69,888	-79,285	-71,096	-21,171
Net energy yield MJ/ha	**284,031**	**287,951**	**267,214**	**7,97**
Output/Input ratio	**5.1**	**4.6**	**4.8**	**1.4**

Table7. ***Energy input output ratios for various crop***(Braun and Weiland 2010)

Those causes together with the temperate climate conditions which the cultivation of maize for silage requires turn it into most widely used energy crop for biogas production in Germany. (Braun and Weiland 2010)

Bulgaria is located over a territory of about 111 000 km². The total area of the land with agricultural purpose in 2010 was 5 492 891 ha which constitute to about the half of its territory. The utilized agricultural area was 5 051 866 ha of which the cultivated land was 3 162 526 ha which is 63% of the utilized agricultural area.

The land used for cultivation of maize for grain was 360 046 ha or 11% of the total cultivated land while the land used for the production of maize silage was 22 265 ha(0.7%). In Bulgaria maize is third most cultivated crop after wheat and sunflower.

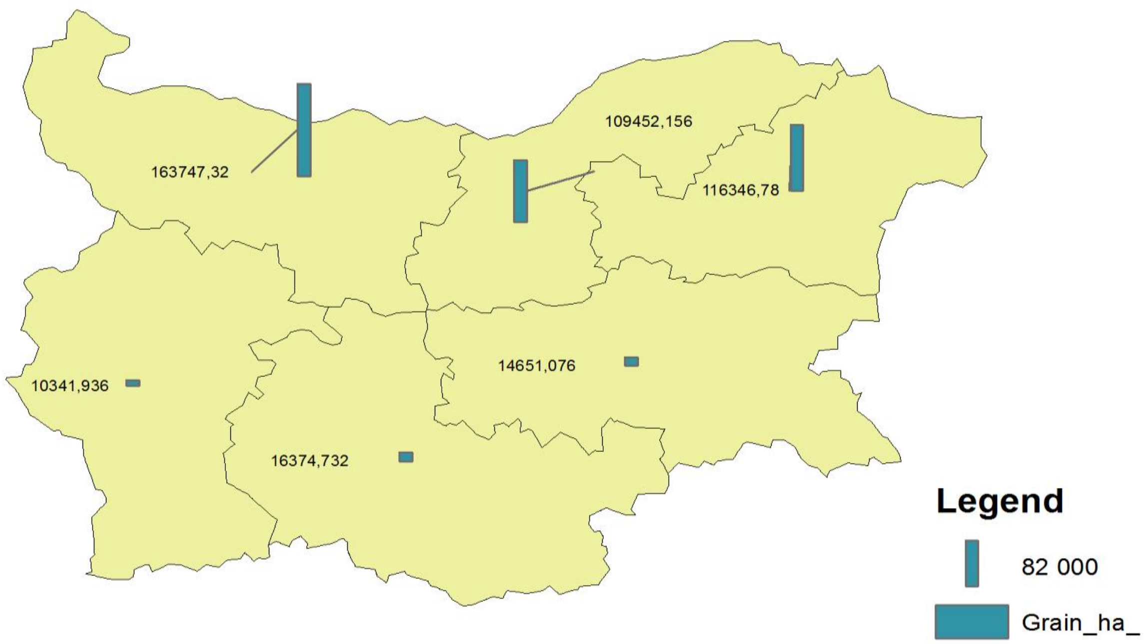


Figure 7. Distribution of land for maize production in Bulgaria (NUTS2)

The maize is mostly cultivated in the North part of Bulgaria. The most of the cultivated maize is in North West area, followed by North East and North central regions. Least maize is cultivated in the South West region.

The climate conditions in Bulgaria which are similar to German's, for net output and traditionally well-established practice in cultivation of maize are reasons maize to considered as the energy crop which might have the greatest potential in Bulgaria as well.

Often maize is a monoculture when it is cultivated as an energy crop, which may lead to soil erosion. The aim to achieve higher yields demands a greater use of fertilizers, pesticides and herbicides (Braun and Weiland 2010). A large scale cultivation of energy crops might create a competition for the land use with food and fodder production. In order not to allow such a competition because the food and fodder production must always have a priority it is assumed the theoretical potential of the available land for energy crops use.

Three main diets are defined – vegetarian, moderate and affluent (Table8). (Holm Nielsen, Oleskowicz-Popiel, and Al Seadi 2007)

[kcal/cap/day]	Vegetarian	Moderate	Affluent
Animal products	166	554	1160
Total requirement	2388	2388	2746

Table 8. The global food requirements according to the three main diets(Holm Nielsen, Oleskowicz-Popiel, and Al Seadi 2007)**.**

The average animal products in the diets are about 15% but their production demands over than 70% of the required land(Holm Nielsen, Oleskowicz-Popiel, and Al Seadi 2007). Therefore the consumption of animal products has an important role in the assessment of the available land for energy purposes.

From the arable land, the minimum land to supply food for population in Bulgaria is calculated. The annual food consumption per person is dependent on diet habits (Table9). The food required per capita have different grain equivalent for the three types of diets (Table9). (Holm Nielsen, Oleskowicz-Popiel, and Al Seadi 2007)

	Vegetarian	Moderate	Affluent
Population of Earth [Billions]	5.9	5.9	5.9
Food requirement [Billion t TS](grain equivalent)	2.8	5.17	9.05
Food/person [tTs/year]	**0.47**	**0.88**	**1.53**

Table 9. Required food per person.(Holm Nielsen, Oleskowicz-Popiel, and Al Seadi 2007)

The current population of Bulgaria is 7.36 million people. The future population can be estimated by considering population growth trend. The population growth rate in 2010 is negative (-4.6%) which is not attributed to natural cause, but to high emigration due to economic situation. So the outflow of population can reversed up if the poor economic situation is changed. However, a negative growth trend is definitively seen from 90's (Fig.8).

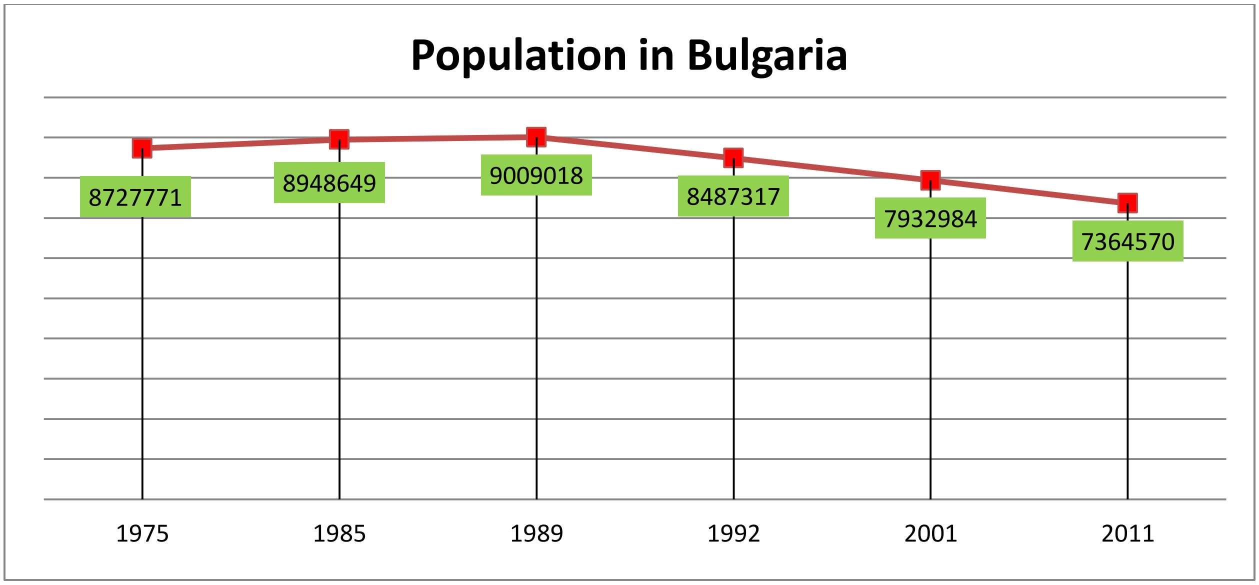


Figure 8. Population trend in Bulgaria from 1975 to 2011 (Ministry of Labour and Social Policy 2011)

According to the projections of National Statistical Institute of Bulgaria(Ministry of Labour and Social Policy 2011), the population will decrease to below 7 million (6.95million) in 2020(Ministry of Labour and Social Policy 2011). If the gradual decrease of the population remains for the future it would decrease the area required for food production and consequently would allow a larger part of the arable land to be used for the cultivation of energy crops. However, in the calculations the current population of 7.36 million people is used.

The grain crop yields vary from year to year for the presented calculation is used average value based on the crop yields from 2009 and 2010 (Table10).

Grain production per Ha in 2009	Grain production per Ha in 2010	Average value
4.71 t/ha	6.25 t/ha	**5.48 t/ha**

Table10. Average grain crop yields from grain 2010 and 2009.

To estimate the potential arable land available for other purposes than providing food is presented the grain equivalent needed to satisfy the food needs of the Bulgarian population (Table 11.). Then the arable land needed for the production of the grain equivalent, respectively for the three types of diets. The result of potentially available land for the vegetarian diet is highest – 2 562 613 ha, moderate diet would provide a potential of 2 023 110 ha to be utilized for nonfood purposes, the affluent diet would allow approximately half the land for nonfood utilization 1 139 874 ha (Table 11).

	Vegetarian	Moderate	Affluent
Population in Bulgaria		**7 360 000**	
Total food requirement in Bulgaria per [t]	3 492 881	6 449 356	11 289 492
Necessary arable land for self-sufficiency [Ha]	637 387	1 176 890	2 060 126
Arable land [Ha]	3 200 000	3 200 000	3 200 000
Potential arable land for other purpose [Ha]	**2 562 613**	**2 023 110**	**1 139 874**
Share of potential area	80%	63%	36%

Table11. Calculation of potential arable land by diet in Bulgaria.

To determine the energy potential, maize for silage is taken as an example crop to be cultivated on the land which is available after the food production considering the three types of diets. According to the authors of (Table.7) (Braun and Weiland 2010), the methane yield of 9 886 m3/ha leads to net energy yield 284 031 MJ/ha. However, according to the calculations in Annex 1 the above mentioned yield must be a result of a crop yield of more than 50 tTS/ha which is rather high and might require an additional irrigation and fertilizers. Therefore, a crop yield of 40 tTS/ha is chosen in order more moderate and realistic results to be obtained. The latter results in net energy yield of 167 552 MJ/ha. Three potential scenarios with respectively 10%, 20% and 30% from the land which is available for nonfood production in the three types of diets are assumed (Fig.9). In the case 10% of the available land is used for maize cultivation that would result in biogas which will have an energy equivalent of about 43 PJ in case of the vegetarian diet, 34 PJ if the moderate diet is applied and 19 if the affluent diet is used. If 20% of the land is used for biogas production from maize silage that would provide energy of 86 PJ for the vegetarian diet, 68 PJ for the moderate and 38 PJ in case of the affluent diet.

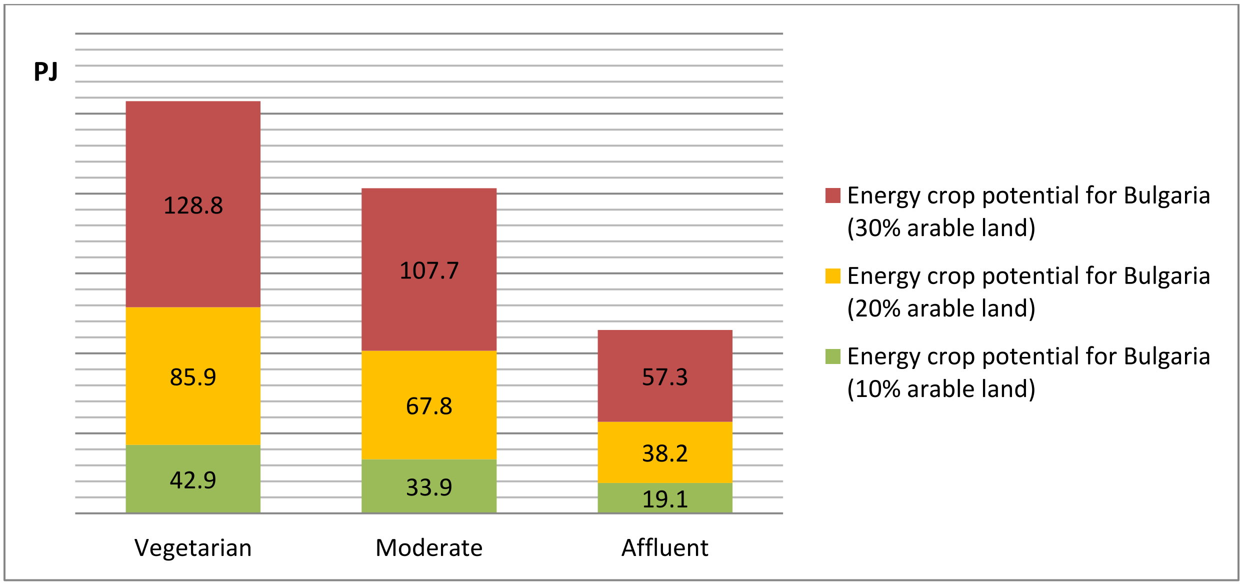


Figure 9. Energy crop potential in energy unit (PJ) in Bulgaria.

Naturally the highest potential is in case if 30% of the available land is used for biogas production from maize silage. In case of vegetarian diet that would result in biogas production of about 129 PJ, if moderate diet is applied almost 102 PJ and if the affluent diet is used that would result in less than half of energy- 57 PJ obtained if the vegetarian diet is used.

Defining the potential for biogas production from energy crops in Bulgaria is a complex task which is related to many constraints. A major one is the need arable land to be allocated for the production of energy crops. Defining the potential land for energy crops growing in general cannot be accurate if only the constraint for food production is taken into consideration. It should be reflected that the cultivation of the arable land is key part of the national agriculture which is an important fundament of the national economy and allocation of significant amounts arable land for energy crop production might influence negatively the current status of the agriculture and consequently to country's macroeconomic indicators as GDP, Export and Import, rate of employment etc.

In addition, even the macroeconomic indicators were not influenced negatively by the large scale utilization of the arable land for energy crop growing there could be environmental impacts as indirect land use effect which would just transfer the problem outside Bulgaria.

There is also the ethical problem with the energy crop cultivation on the farmland while there are millions of people starving people all over the entire planet.(Jørgensen 2009)

Even if it assumed that 30% of the arable land can be used for energy crops it is hard to be defined what would be the share are going to be used as a co-substrates for biogas production that will be determined by the market. The two main scenarios are considered as most realistic:

1. Moderate food died – with 10% land allocated for maize cultivation will result in 1 541 MCM/a biogas and energy equivalent of 33.9 PJ;
2. Moderate food diet - with 20% land allocated for maize cultivation will result in 3 082 MCM/a biogas and energy equivalent of 67.80 PJ.

One way the energy/food competition can be mitigated is through maximized utilization of non-farmed lands which are around 4% of land with agricultural purpose or about 220,000 ha and permanent grass lands 33% or 1 702 000 ha. (Ministry of Food and Agriculture 2011)

Maize as a crop was taken as an example for mass cultivation and further biogas production. It good input/output ratio (Table7) and high methane yield are main reasons for that but it should be also considered that those results are taken in the German climate conditions. Although, Bulgarian and German climate conditions are similar they can also differ especially in the summer. The hot and dry periods of the summers in Bulgaria could be prerequisites which might hinder the achievement of high crop yields. Thus the role of other energy crops like fodder beet, potatoes, sorghum, Sudan grass should not be underestimated because they might be more appropriate in terms of soil and climate conditions.

For e.g. sorghum has a lower methane yield and also poorer input/output ratio compared with the maize but it has an advantage, during a periods of extreme drought it hibernates and temporary suspend its growth and quickly restores it in a presence of moisture.

3.3 Conclusion

As it is clearly seen on Table 12 the assumed realizable potential for biogas production in Bulgaria have energy crops followed by straw for residues and animal manure. A way less potential has household waste then comes sewage sludge and food industry waste has the least potential for biogas production.

Biogas potential	[MCM]
Sewage sludge	43
Household waste	85
Food industry waste	23
Straw and residues	774
Animal manure	504
Energy crops	1 541
Total	**2 970**

Table 12. The potential for biogas production in Bulgaria from the major biomass resources.

The energy potentials for the production of biogas from different biomass resources in Bulgaria (Fig.10) are presented in two case scenarios. The first case represents the present total calculated potential of 119.7 PJ from all of the included biomasses. Second column illustrates the assumed realizable potential of almost half of the total potential 65.3 PJ. The total inland energy consumption of Bulgaria in 2010 was 745 PJ. The biggest potential in the both cases has the energy crop production – respectively 67.8 and 33.9. Second largest potential is from straw and residues, in the case with the total potential it is 25 PJ whilst the assumed realizable potential is assumed to be 17 PJ. Animal manure possesses the third largest potential, 22.2 PJ which is with 50% more than it assumed as realizable.

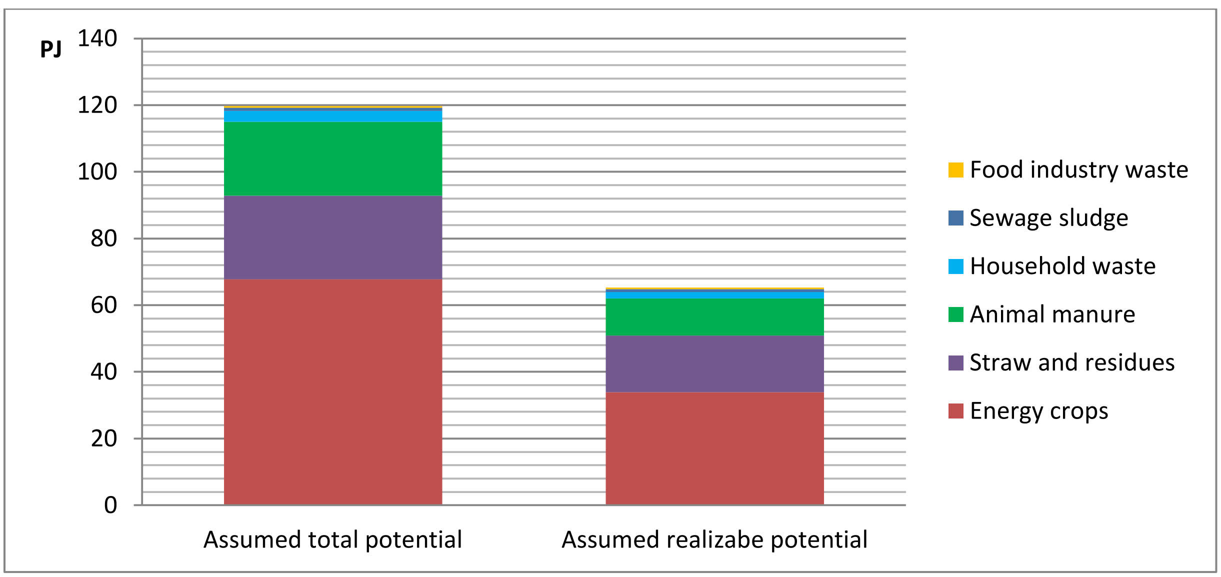


Figure 10. Energy potentials for biogas production from different biomass.

Households waste is considered to have fourth largest potential, 3.3 PJ total potential and 1.9 PJ realizable potential.

Least potential for biogas production in both cases have sewage sludge and food industry waste. The potential of the food waste is assumed to be 0.5 PJ continuous for total and realizable potential. The potential of the sewage sludge for biogas production in Bulgaria also remains the same as assumed and realizable.

4. Socio economic feasibility study

The chapter contains the socioeconomic feasibility study and analysis of a certain socioeconomic consequences from the utilization of the potential for biogas production in Bulgaria in CHPs.

4.1 Defining the purpose of the study

In order to answer to the research question the present feasibility study aims to evaluate the socioeconomic impacts for the Bulgarian society from the implementation of a new for the country technology such as is biogas and its utilization in CHP. In the sense of impacts are considered the variety of costs but also benefits in the case the assumed realizable potential for biogas is implemented in Bulgaria.

4.2 Organizational goals

The implementation of biogas technology on large scale and its utilization for electricity and heat production might be nationally significant in terms of achieving various socioeconomic objectives . The ones which are considered as major in the present study are:

- Decrease the energy dependency of the country by reducing the expected growing import of natural gas from Russia through utilization of locally based renewable resources;
- Support the employment considering the conditions with high unemployment rate in the country;
- Decrease the GHG emissions in accordance with the national and pan EU goals.

The achievement or contribution to the above mentioned organizational goals are outlined as main criteria in the assessment of the proposed alternatives and it must be assessed in the context of least costs for the Bulgarian society.
The range of areas in the socioeconomic life over which the large scale implementation of biogas might have an impact exceeds the ones which are particularly taken into account. Additional objectives of such a study would be the opportunity for technological and economic development which the adoption of a wide spread and proven technology offers. The waste management of can be significantly improved by its use in the AD process. The use of agricultural feedstock for biogas production can create an opportunity for additional income for the farmers and thereby stimulate the development of the Bulgarian agriculture, which is an important sector of the country's economy. AD process for biogas

production offers an additional benefit for the farmers and that is the digested biomass which can be utilized as a fertilizer and replace the use of artificial fertilizers (Jørgensen 2009).

4.3 Constraints in determination of the alternatives

3.3.1 Constraints related to heat and electricity sector

The fact that there is a certain potential for biogas production in Bulgaria doesn't alone determines the need it to be utilized for energy production. In case the potential is going to be utilized in CHP plants country's electricity and heat demand is the most important rationale which can justify the initiation of the implementation and utilization of the biogas potential in Bulgaria.

The gross electricity generation in Bulgaria has increased with almost 5TWh from 41.7 TWh to 46.6 TWh between 1995 and 2010 (Fig.1). The main fuels for electricity production for the whole period have been solid fuels, which even increased its part from 17.3 TWh to 22.6 TWh. The second most important fuel source is the nuclear although it has decreased due to the decommissioning of two of the blocks of the nuclear power plant "Kozloduy". Nuclear delivers 15.2 TWh in 2010 which about 33% of the gross electricity generation of the country. RES has been increasing their share gradually from 0.06% in 1995 to almost 14% in 2010 which equals 6.4 TWh. Less impact on the electricity generation has natural gas which use decreased from 3.4 TWh in 1995 to 2 TWh in 2010. Petroleum products have least significant impact, the electricity generation from them declined from 1 TWh in 1995 to 0.4 TWh in 2010.

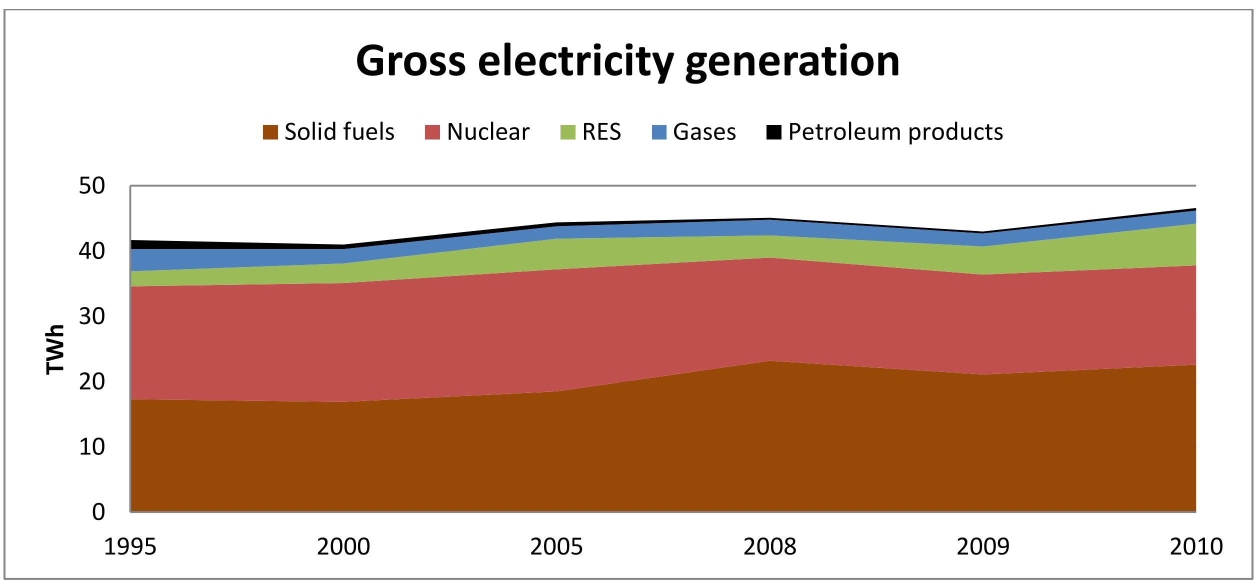


Figure 1. Gross electricity generation in Bulgaria by fuel sources between 1995 and 2010.(Commission 2012)

Important implications over the potential use of biogas for CHP have the projections about the future lifetime of the currently running base load coal power plants.

The base load of the Bulgarian electricity system is covered by:

- Block 5 and 6 of the Kozloduy nuclear power plant with installed capacity – 2000 MW;
- Coal based CCHP plant "Maritza Iztok 1" with installed capacity - 600 MW;
- Coal based CCHP plant "Maritza Iztok 2" with installed capacity - 1450 MW;
- Coal based CCHP plant "Maritza Iztok 3" with installed capacity - 880 MW;
- Coal based CCHP plant "Bobovbdol" with installed capacity – 430 MW;
- Other CHP plants – 220 MW (Bulatom 2013).

Bulgaria has in total 5580 MW installed capacity to cover the base load. The projections for the current plants are showing that there are two options for the nuclear power plant in Kozloduy:

1. To be decommissioned between 2019 and 2020;
2. By the end of 2013 to be made a programme for it modernization and extension of its lifetime (Bulatom 2013).

The projections concerning the lifetime of the coal based CCHP power plants:

1. "Maritza Iztok 1" lifetime till – 2050;
2. "Maritza Iztok 2" lifetime till – 2030;
3. "Maritza Iztok 3" lifetime till – 2030;
4. "Bobovdol" lifetime till - 2020 (Bulatom 2013).

In case that the nuclear power plant in Kozloduy is decommissioned by 2020 the projections show a decrease of 2430 MW from the installed capacity which is responsible for covering the base load of the Bulgarian electricity system. By the year 2030 the two biggest coal based CCHP will be decommissioned and that would reduce the installed capacity with 2330 MW. As a consequence of that by 2030 Bulgaria will have only 820MW capacity to cover its electricity base load which is a reduction with almost 85% compared to 2013. As a matter of fact governmental authorities planned to solve the problem by introducing the project of building a second nuclear in 2006 but due to the financial resources the project was officially abandoned.

The future projections show that there will be a demand for installing new electricity capacities in Bulgaria which is an opportunity for the biogas to be utilized in the high efficient and proven technology as CHP. The large implementation of biogas plants together with CHP can be an opportunity for partial decentralization of the electricity production in Bulgaria.

The installed electrical capacity of CHP technology in 2010 in Bulgaria was 1000 MW which generated 3.7 TWh or 8% from the electricity generation (Commission 2012). The heat production in the CHP plants in the country for 2010 was 40.4 PJ (Commission 2012). The amount of the utilized fuels in CHP plants in 2011 were 67.7 PJ.

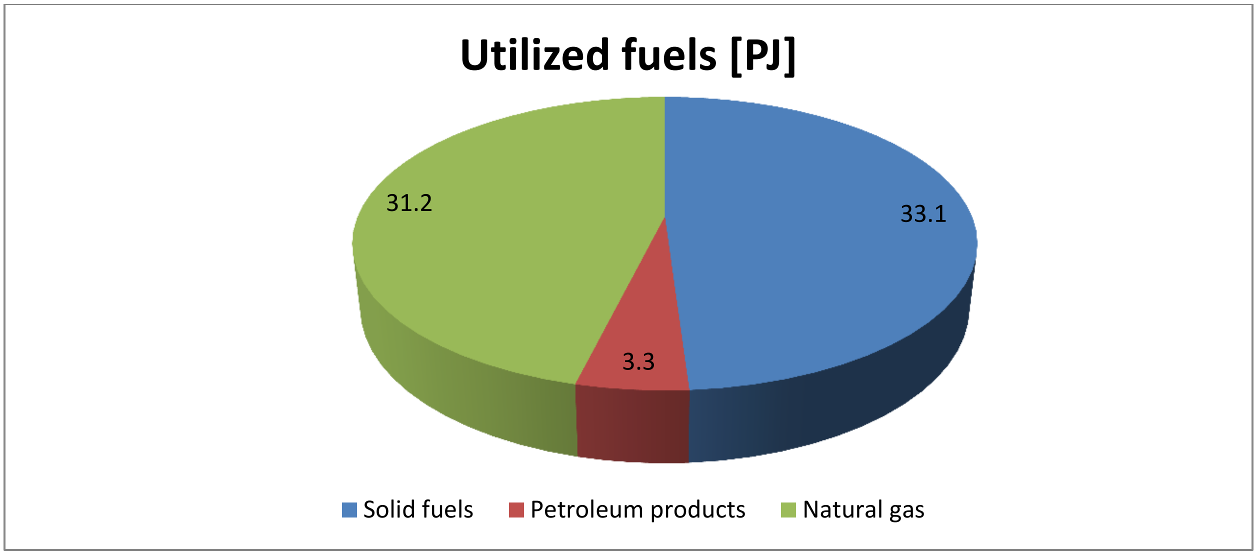


Figure 2. The fuels used in CHP plants in Bulgaria(2011)(National Statistical Institute 2012)

The most important fuel for CHP plants in 2011 were solid fuels with 33.2 PJ followed by natural gas 31.2 PJ and petroleum products with only 3.3 PJ. Although, solid fuels are the most used in the CHP plants in Bulgaria, in the terms of import in 2010 their share was 24.7% in comparison to the natural gas 95.1% of which was imported in the country in the same year (Fig2). The highest import dependency Bulgaria had from the petroleum fuels which kept around 100% during the whole period between 1995 and 2010. In overall Bulgarian dependency on fuel import declined from 57.2% in 1995 to 40.3% in 2010.

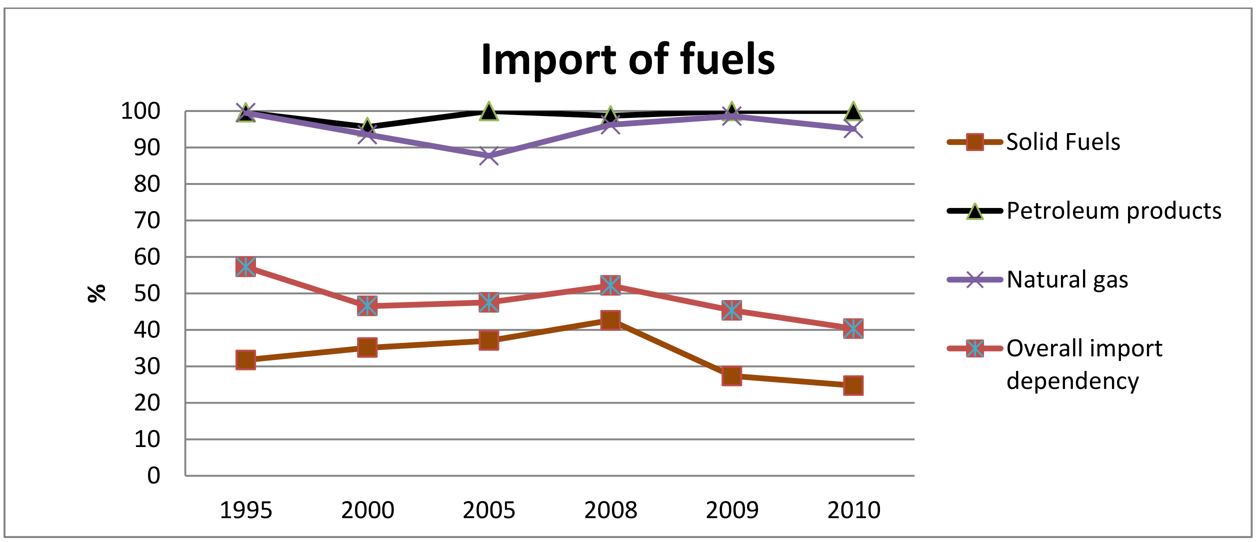


Figure 2. Imports of fuels in Bulgaria between 1995 and 2010 (Commission 2012)**.**

The total import of natural gas in Bulgaria in 2010 was 122.4 PJ from which only 31.2 PJ are used in CHP plants as a fuel.

The heat produced by energy plants in Bulgaria in 2011 was 14.6 TWh which is with 3.6 % less than 2010. The biggest producers of heat in Bulgaria are the district heating companies with 50.6% and respectively 8.3 TWh(Fig3). The industry is the second biggest producer with 47.7% or about 7TWh.

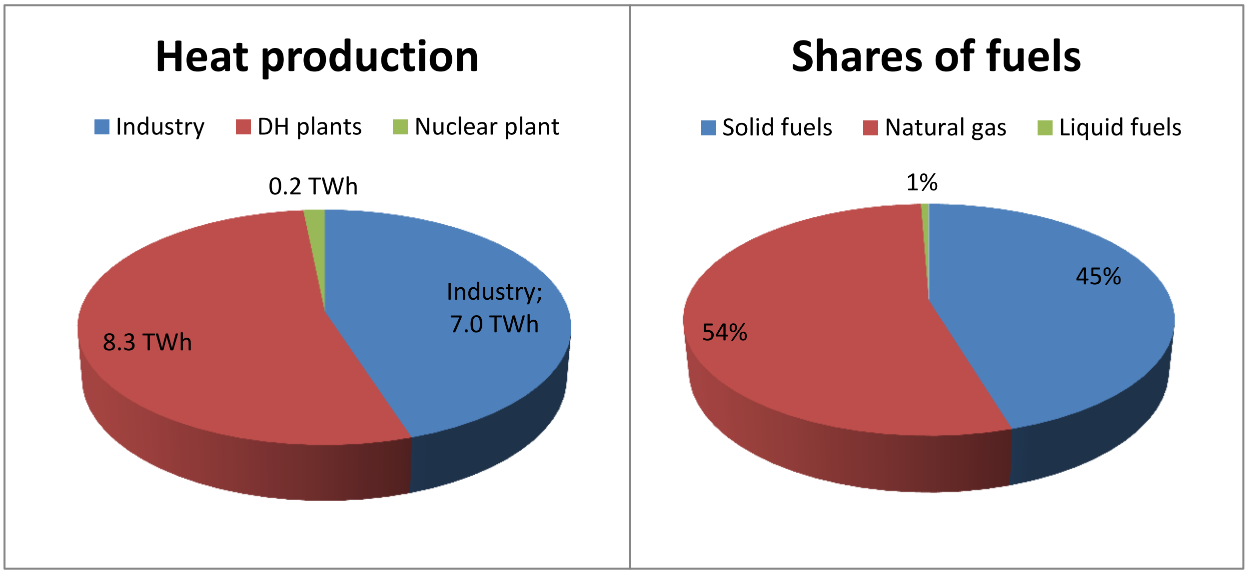


Figure 3. Heat production in Bulgaria 2011 (Ministry of Economy,Energy and Tourism 2012)
Figure 4. Shares of fuels used for heat production 2011(Ministry of Economy,Energy and Tourism 2012)**.**

The nuclear power plant at Kozloduy produced only 0.2 TWh or only 1.7% of the total produced heat.(Ministry of Economy,Energy and Tourism 2012)

The major share of the fuels utilized for heat production has natural gas 54% whilst solid fuels' share was 45% (Fig.4). The modest share of 1% was for the nuclear.

The consumption of heat in the country was 11.4 TWh, the main consumer was industry with 6.2 TWh, followed by households with consumption of 4.3 TWh. The budgetary organizations consumed only 0.8 TWh (Ministry of Economy,Energy and Tourism 2012).

The "National Energy Strategy of Bulgaria - 2020" states that one of the priorities in energy sector policy is going to be the support to energy produced with CHP technology, even though the specific measures for such a support are not presented (Ministry of Economy,Energy and Tourism).

In accordance to the same energy strategy the electricity generation from CHP plants in Bulgaria will increase more than four and a half times from 3.7 TWh in 2011 to 17 TWh in 2015. The electricity generation from CHP is expected to be 15.1 TWh and 13.1 TWh respectively in 2020 and 2030. (Ministry of Economy,Energy and Tourism)

The expected increase of the electricity generation from CHP plants in any case will lead to the utilization of natural gas. Consequently would lead to increase of country's energy dependency on the import of natural gas from Russia. However, an increase in the electricity generation from CHP is not necessarily equivalent with an increased import of natural gas, as it is possible to utilize locally based resources, such as biogas.

4.3.2Constraints related to biogas conversion technologies

Some of the characteristics of biogas determine its utilization. From 55% up to 70% of biogas chemical composition is methane (CH_4) (Table1). Carbon dioxide has second biggest shares, from 30-45%. Insignificant parts of biogas chemical composition, varying between 1-2% have hydrogen sulfide (H_2S), hydrogen (H_2) and ammonia (NH_3). There are also traces of carbon monoxide (CO), Nitrogen (N_2) and oxygen (O_2). Biogas is flammable because of the methane and hydrogen content. The composition of CH_4 or CO_2 in the biogas depends on the type of feedstock or their combination in the production process. (Jørgensen 2009)

Gas	%
Methane (CH_4)	55-70
Carbon dioxide (CO_2)	30-45
Hydrogen sulfide (H_2S)	1-2
Hydrogen (H_2)	1-2
Ammonia (NH_3)	1-2
Carbon monoxide (CO)	trace
Nitrogen (N_2)	trace
Oxygen (O_2)	trace

Table1. The chemical composition of biogas.(Jørgensen 2009)

Biogas is combustible and that allows it to be used as fuel by utilization of various energy conversion technologies. These technologies are already used for energy conversion of natural gas which is again primarily composed of CH_4 (90-98%). Biogas can be directly combusted in boilers or burners for heat production. That technology offers efficiency of around 85% (Jørgensen 2009).
Biogas can also be used as a fuel for vehicle with internal combustion engine after it is upgraded. That application of biogas is constantly growing especially in countries like Sweden and Germany. The vehicles which run on biomethane (upgraded biogas) has a great advantage in terms of decrease of CO_2 emissions.(Al Seadi, Rutz, and Janssen 2008)

Another application of biogas can in fuel cells so the chemical energy can be converted straight to electrical. There are different types of fuel cells dependent on the type of used electrolyte. Those are *Polymer Electrolyte Membrane Fuel Cell* (PEMFC), *Phosphoric Acid Fuel Cell* (PAFC), *Molten Carbonate Fuel Cell* (MCFC) and *Solid Oxide Fuel Cell* (SOFC) (Al Seadi, Rutz, and Janssen 2008). Depending on the temperature fuel cell can be divided to low temperature PAFC and PEMFC, medium PAFC and high MCFC and SOFC. Usually biogas is used in MCFC and SOFC they respectively have efficiency 45-50% and 60%. In order to increase the efficiency fuel cells can be coupled with turbine they can operate in CHP system.

Application of biogas in fuel cell is still not deployed mainly due to the high investment costs in comparison to the other alternatives for biogas use (Al Seadi, Rutz, and Janssen 2008).(Jørgensen 2009)

The most common use of biogas for energy production is in CHP generation due its high efficiency, from 80% up to 90%, respectively electrical efficiency 35-40% and thermal 50-55%. The typical kind of CHP plants is the block type thermal plant (BTTP) with combustion motor(s) combined to a generator. The engines are *Gas Otto,Gas-Diesel* and *Gas –Pilot Injection.* An alternative of the BTTP engine could be also a micro gas turbine but they have electrical capacity usually under 200 kWe (Al Seadi, Rutz, and Janssen 2008). The BTTP engines have certain advantages in CHP operation system compared to their alternatives – fuel cells and micro gas turbines, following the ratio between efficiency and investment costs.

4.4 Setting the alternatives

According to the organizational goals and the above described constraints three mutually comparable alternatives are proposed. Mutually comparable in the sense of input i.e. the energy potential of the biomass and output i.e. production of electricity and heat. Considering the DM content of the total biomass is assumed that wet digestion in continuous biogas co-digestion is going to be used for all the biogas plants. The CHP units are assumed to use gas engines. The electrical efficiency of 45% and thermal 45% are considered for all the energy production units (Agency and Energinet 2010).

Geographical deployment of both biogas and CHP plants are not considered in the study.

The first alternative is biogas/ energy crops. It considers the amount of assumed realizable potential of 65.3 PJ from which is excluded the sewage sludge as it requires a relatively different technology for AD process which cannot be used in co digestion process with the rest of biomasses. Biogas/energy crop alternative has an energy potential of 64.4 PJ as it can be seen in Table2. The largest potential has energy crops with about 60% of the whole assumed realizable potential. The energy crops potential is estimated considering a moderate food diet and 10%. Straw and residues from cereals have second high potential which is around 30% of the total. Then follow the potential from animal manure, household waste and food industry waste.

Energy potential PJ	
Household waste	1.9
Food industry waste	0.5
Straw and residues	17
Animal manure	11.1
Energy crops	33.9
Total	**64.4**

Table 2. The energy potential of the waste/energy crops alternative.

An important consideration for defining the potential for the alternative is the goal to implement as much as possible waste resources and in addition energy crops which are locally produced feedstock.

As the basic concept of the alternative shows in Figure 5 the biomass is transported to the plant where after the AD process biogas and digested biomass are produced. The potential is assumed to be utilized in decentralized CHP plants. The electricity will be generated in the national electricity grid while the heat can be utilized for heating the biomass in the biogas plant and the rest of the heat might be available for other purposes e.g. district heating or in various industrial processes.

The deployment of biogas plants is assumed to be strongly dependent on the geographical distribution of biomass because it transport costs are one of the crucial factors which can define the capacity of the biogas plant from business economic point of view. There are also organizational and financial aspects which can influence the capacity of a potential biogas plant.

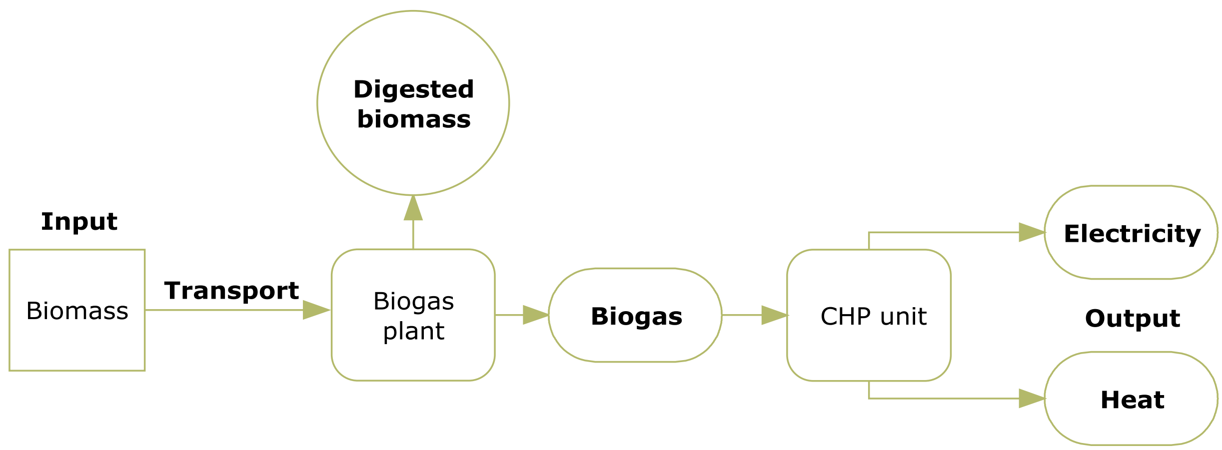


Figure 5. The simplified concept of Alternative 1.

For the presented alternatives which include biogas production, capacity of the biogas plants of 300 t/d is chosen. The size defines the plants as centralized in order to represent a case in which a given plant will use all the variety of the available biomasses which differ from the concept of farm size plants based only on manure and energy crops. Consequently, the capacity of the biogas plant and its biogas output will define the capacity of the CHP unit for the given alternatives.

The total amount of 42 072 667 t, of biomass is assumed to be annually available for biogas production in Bulgaria, whilst the daily intake is 115 268 t (Table3).The daily plant share of 73% of the animal manure is the largest amongst the all biomasses in co-digestion. Second and third come respectively energy crops with about 20% and straw from cereals with 5%. The negligible is the share of household waste and food industry waste with about 1% each.

Biogas plants intake	t/a	t/day	plant t /day
Household waste	476 000	1 304	3
Food industry waste	389 000	1 066	3
Straw and residues	2 313 518	6 338	117
Animal manure	30 801 708	84 388	220
Energy crops	8 092 441	22 171	58
Total	**42 072 667**	**115 268**	**300**

Table 3. Total amount of biomass distributed annually and daily.

The yearly production of biogas is equals 2927.3 MCM if it is assumed an average yield of 70 m^3/t biomass which is distributed amongst 384 biogas plants. The annual biogas production has an energy potential of 64.4 PJ (Table2). The annual electricity generation is 8.05 TWh, the total heat production is 28 980 TJ. The heat which would be used for heating of biomass is assumed to be 20% and additional 10% of heat loss thus the heat available for other purposes is 20286 TJ (Olesen and Bedi 2006). The total installed capacity of 1076 MWel is assumed.

The second alternative is waste / natural gas (NG). It includes the same potential from waste materials as the first alternative but the energy crops potential is replaced with natural gas (Table3). The exclusion of energy crops would lead to the use only of feedstock for biogas production considered as wastes material whilst energy crops lead to the creation of additional production activity. Thus, the biogas production would be in a way more sustainable.

An essential argument the energy crops to be excluded are the constant debates related to the food against energy is some of the European countries (Jørgensen 2009). Although, it was shown earlier in the report that theoretically there is a potential chance in Bulgaria the energy crops to be used for biogas production without land used for food production to be occupied, there are still people starving all over the world. The use of arable land for dedicated energy crops might also lead to competition with its use for other agricultural production. There is an ambiguity which of both would have more positive impact over the agriculture and national economy in general. Apart from the economic and moral issues the dedicated energy crops cultivated as monocultures e.g. maize have also negative environmental effects as a loss of biodiversity, soil depletion. Another negative impact from the cultivation of dedicated energy crops would be the extensive use of fertilizers which will be required in order higher crop yields per hectare to be achieved. (Braun and Weiland 2010)

Energy potential PJ	
Household waste	1.9
Food industry waste	0.5
Straw and residues	17
Animal manure	11.1
Natural gas	33.9
Total	64.4

Table 3. The energy potential of the waste/NG alternative.

The energy potential is kept the same as it is in the case of waste/energy crops alternative, the amount of energy potential of the biogas produced from energy crops equals the one which considers natural gas. The NG is expected to cover almost 53% of the total energy input of 64.4 PJ.

The concept of the alternative concerning the biogas production is the same as it is described above for the first alternative (Fig.6). The NG which is determined to be a replacement of the biogas produced from energy crops is assumed to be imported from Russia and delivered to the CHP plants via national gas grid and it is utilized using the same technology as the biogas.

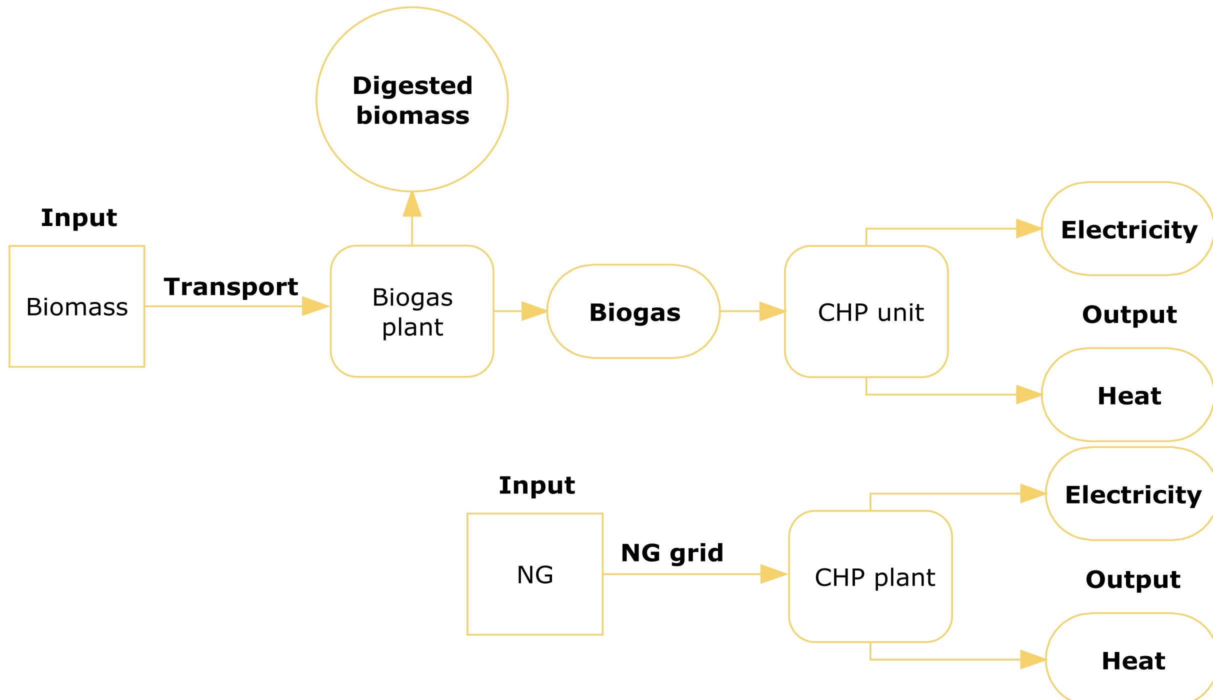


Figure 6. Simplified concept of Alternative 2.

The capacity of the biogas plants is kept the same 300 t/d. The annual intake of different feedstock is 33 980 226 t, which determines a daily of 93 097 t (Table 4). The share of 91% the animal manure in the daily amount of substrate for one plant is largest. The part of the straw is 7% from the total 300 t, while the household and food industry wastes constitute of 1% each.

Biogas plants intake	t/a	t/day	plant t/d
Household waste	476 000	1 304	4
Food industry waste	389 000	1 066	3
Straw and residues	2 313 518	6 338	20
Animal manure	30 801 708	84 388	272
Total	**33 980 226**	**93 097**	**300**

Table 4. Total amount of annually and daily distributed biomass.

The annual biogas production from all 310 plants equals 1386.5 MCM, the average biogas yield of 41 m^3/t is used (Olesen and Bedi 2006)(Agency and Energinet 2010). The electricity generation from the biogas is 3.8 TWh annually whilst the total heat production is 13 725 TJ. Considering the own consumption and the heat loss the net heat available for other purposes is 9 608 TJ. The installed capacity of the CHP units which use biogas is 528 MWel.

The amount of the NG is estimated to 916.2 MCM considering the 37 MJ/m^3 lower heating value of the natural gas. The annual electricity generation is 4.2 TWh, the heat production is 15 250 TJ. The installed capacity of the CHP plants which are using NG is 548 MWel.

The total electricity production equals the one of waste/energy crops alternative of 8.05 TWh/a while the net supplied heat is with 4 800 TJ more than the first alternative due to the less losses and less own demand.

In the third alternative is assumed 100% NG to be used with the same energy potential of 64.4 PJ as in the other two alternatives. The alternative is set in order to estimate the costs for the Bulgarian society in case locally produced biogas is not utilized for electricity and heat production but instead Russian NG is used (Fig.7). The NG is utilized as fuel in CHP.

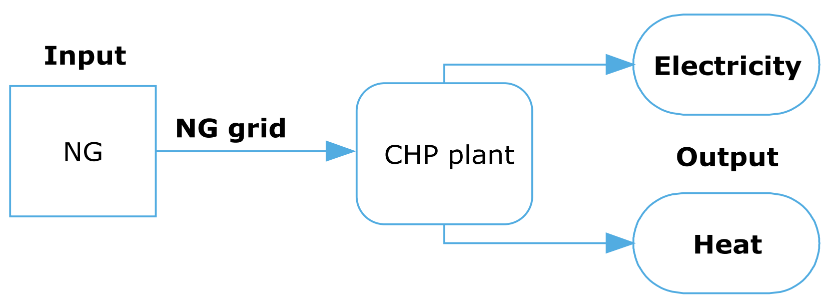


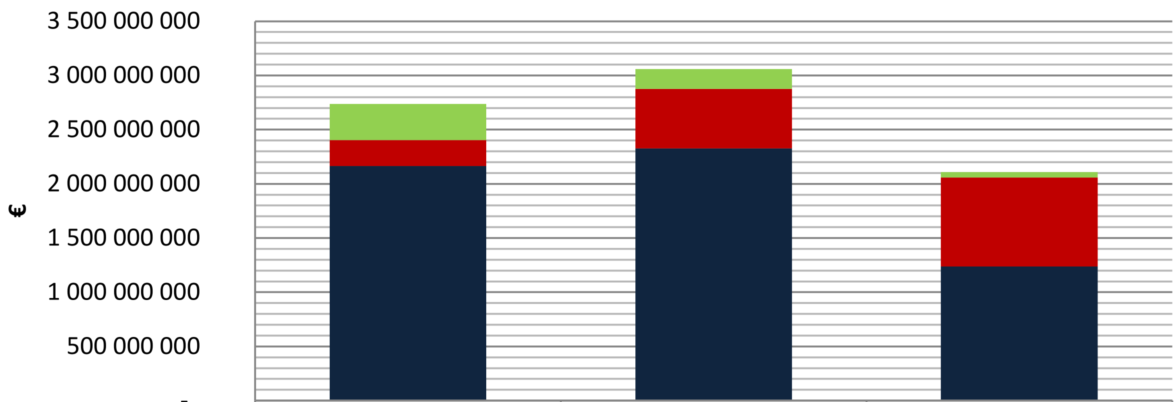
Figure 7. Simplified concept of NG alternative

The annual NG used is 1 741 MCM respond to 64.4 PJ considered heating value of the gas is 37 MJ/m^3. The electricity generation equals the previous two alternatives while the produced heat is higher because it is not needed for internal needs.

4.5 Evaluation of the socioeconomic impacts of the three alternatives

The total investment costs, annual O&M costs and annual external costs for the three alternatives are presented in Figure 8.

The highest investment costs of 2 327 986 160 € has waste/NG alternative, the second highest is for waste/energy crops alternative with 2 163 188 285 € while a way lower investment costs of 1 237 205 378 € has NG alternative. However, NG alternative has highest annual O&M of 820 993 364 € which are more than 3 times than the waste/energy crops alternative which are 241 499 688 €. Annual O&M cost of the waste/NG alternative are 546 552 814 € which are still significantly less than the NG alternative.



	Alternative 1	Alternative 2	Alternative 3
External costs [b]	332 452 209	183 129 002	50 749 437
O&M[a]	241 499 688	546 552 814	820 993 364
Investment costs[a]	2 163 188 285	2 327 986 160	1 237 205 378

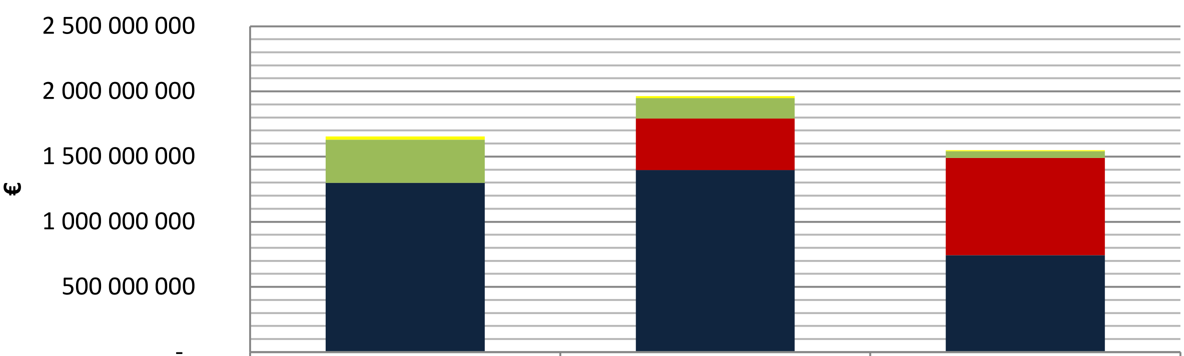
Figure 8. Total investment costs, annual O&M and annual external costs for the three alternatives
a=(Agency and Energinet 2010);**b**=(Commission 2003)**.**

The large O&M costs for "Alternative1" and "Alternative2'are due to the high fuel costs for NG. The greatest annual external costs of 332 452 209 € are accounted for "Alternative1" which are about 6 time more than "Alternative3" which has 50 749 437 €. The annual external costs for "Alternative2" amount to 183 129 002 € which is still considerably less than the annual external costs of "Alternative1". The costs displayed on the Figure8 are the costs which would be taken into account in case the import share for the investment and O&M costs is considered to 100%.

However, considering the goal of the socioeconomic feasibility study only the import share of the costs is counted as cost for the Bulgarian society.

Even though the main technology equipment is assumed to be imported from abroad is assumed that 40% of the investment cost will be domestic. The O&M costs which don't include fuel costs are considered to have an import share of 10%. The fuel costs for the waste/energy crops alternative and the part of waste/NG which uses biogas as a fuel are considered as 100% domestic costs thus they are not included as costs for the Bulgarian society. In the cases of "Alternative2" which partly uses NG and

"Alternative3" which uses fully NG the fuel costs are considered as 100% imported and therefore there are accounted as costs for the Bulgarian society.



	Alternative 1	Alternative 2	Alternative 3
O&M[a]	24 149 969	15 252 111	7 245 000
External costs[a c]	332 452 209	156 959 337	50 749 437
Fuel[a b d]	0	394 031 704	748 543 364
Investment costs[a]	1 297 912 971	1 396 791 696	742 323 227

Figure 9. The investment costs, annual O&M and external costs for the Bulgarian society a=(Agency and Energinet 2010)**;b=**(International)**;c=**(Commission 2003)**;d=**(Commission Regulatory, State,Energy,Water 2013)**.**

The investment costs are calculated considering the change of the price for the technology between 2010 and 2030 (Agency and Energinet 2010). As it is clearly seen on Figure 9 the investment costs of the "Alternative 2" are 1 396 791 696 € which is about 100 million more than "Alternative 1". The investment costs of "Alternative 3" are 742 323 227 € drastically less than the two other alternatives. The annual O&M costs are shown separately in order the significance of the fuel costs to be displayed. The annual fuel costs are highest for NG alternative and amount to 748 543 364 € while for waste/NG they are 394 031 704 €. The fuel costs are calculated considering the present price of the NG for the power plants and projected increase till 2030(International). The annual external costs are 332 452 209 € for waste/energy crops alternative which is twice as much as the ones for waste/NG and about 6 times more than the NG alternative. The O&M costs of "Alternative 1" are also a way higher compared to the other two alternatives.

Aiming to give an objective reflection over the impacts for the Bulgarian society from the implementation of biogas the research comprise not only costs but also benefits from the utilization of some of the waste biomasses in AD process (Table 5).

Three main groups of impacts are considered. First is the impact over the agriculture which comprises storage savings from the manure, transport savings in agriculture, the value of the improved fertilizer and the value of the reduced obnoxious smells. The second impact category is related to waste and only includes the savings which relate to the organic waste treatment. It value is calculated considering the total amount of both household and food industry waste. The third category reflects upon the impacts over the environment and includes the value of the reduction of GHG, value of the reduced eutrophication from liquid manure and value of the reduced N-eutrophication from spreading organic waste.

Annual monetized benefits from biogas production		Alternative 1	Alternative2
Agriculture	Storage savings from manure €/tonnes manure	2 890 241	2 890 241
	Transport savings in agriculture€/tonnes manure	1 445 120	1 445 120
	Value of improved fertilizer €/tonnes manure	22 337 432	22 337 432
	Value of the reduced obnoxious smells €/tonnes manure	14 451 203	14 451 203
Waste	Savings related to the organic waste treatment €/ton organic waste	10 145 777	10 145 777
Environment	Value of the GHG reduction €/tonnes biomass	88 352 601	71 358 475
	Value of reduced N-eutrophication from liquid manure €/ tonnes manure	8 439 503	8 439 503
	Value of reduced N-eutrophication from spreading organic waste €/tonnes	224 830	224 830
Total		**148 286 70** €	**131 292 582** €

Table 5. The annual monetized benefits from utilization of waste biomass for waste/energy crops and waste/NG alternatives (Nielsen and K. Hjort-Gregersen 2002)**.**

The annual monetized benefits from the utilization of waste/energy crops alternative are 148 286 708 € which is with about 17 million euro more than the waste/NG alternative. The difference is a result of the higher value of the GHG reduction in the case of "Alternative1" which derives from the greater amount of biomass treated because it includes the energy crops.

In order to compare the socioeconomic costs which would be a result from the implementation of the three alternatives a comparison of their EAC(Equivalent annualized costs) is made. The EAC are considered as a sum of the import share of EAIC(Equivalent annualized investment costs), import share of the annual O&M costs, annual external costs and the subtraction of the annual monetized benefits from the utilization of the used biomasses.

	Alternative 1	Alternative 2	Alternative 3
EAIC [€]	**38 937 387**	**41 903 749**	**22 269 695**
EAC [€]	**247 252 857**	**476 854 319**	**828 807 496**

Table 6. EAIC and EAC for the three alternatives.

The highest EAIC has "Alternative 2" which has also highest initial investment costs (Table 6)." Alternative 3" has lowest EAIC which is due to its lowest initial investment costs but also because the lifetime of it investment is considered to be 25 years whilst the lifetime for “Alternative 1” and “Alternative 2” is 20 years.

As it is clearly indicated in Table 6 waste/energy crops alternative has EAC of 247 252 857 € which is the lowest compared to the other two alternatives and therefore it is the most cost effective alternative from socioeconomic point of view. The main reason which leads to the lowest EAC in the case of “Alternative 1’ is the lack of fuel costs and respectively the higher EAC for the “Alternative 2” and highest EAC for “Alternative 3” are result of their higher annual costs for NG.

Considering the results of EAIC and EAC of the three alternatives it can be concluded that the annual fuel costs are a way more significant than the initial investment costs and annual external costs over the EAC. The significance of the fuel costs are outlining the “Alternative3” as the worst while their lack in the case of “Alternative 1” is defining as the best from socioeconomic point of view.

4.6 Employment effects of the three alternatives

Taking into account the high unemployment rate of 12.4% in Bulgaria for 2012 the potential significance of the three alternatives over the job creation is considered as an important socioeconomic effect (National Statistical Institute 2013).

The first method used for the calculations of the employment effect of the three alternatives is based on the domestic share of the investments. For the alternatives with biogas are used 17 persons employed per million euro while for the NG plants 12 persons per million euro (Hvelplund 1998).

As it seen in Table 7 the greatest effect on the employment has the waste/energy crops alternative creating 5 566 298 man years, more than 2 times than the NG alternative which has a lifetime of 25 years. If NG gas alternative has the same lifetime period of 20 years then it would result in 1 910 057 man years which would make the difference between the employment effects of the two alternatives even greater. The second high employment effect has waste/NG alternative creating almost 600 000 man years than the waste/energy crops alternative.

Alternative 1	
Total employed persons for all the plants for 20years lifetime[a b]	19 482
Employment man years for 20 years lifetime [a b]	5 566 298
Alternative 2	
Total employed persons[a b]	17 393
Total man years[a b]	4 969 344
Alternative 3	
Total employed persons for all the plants for 20years[a b]	6 685
Employment man years for 20 years[a b]	1 910 057

Table 7. The employment effects of the three alternatives (Hvelplund 1998)**.**

The second method is used only to compare the different employment effects between the two used methods in the case of “Alternative 1”. The method assumes 19 people to be employed per

MWel(Lovrenchec). The method shows a slight difference of 1000 persons more employed and more than 270 000 man years than the method based on the investment (Table8).

Alternative 1	
Mwel	1 076
Employment persons per MW	20 441
Employment man years for 20 years lifetime of the investment	5 840 224

Table 8. The employment effects of the biogas plants investment per MWel (Lovrenchec)**.**

The employment effects of "Alternative 1"is proven as greatest compared to the other two alternatives but is also fair to be mentioned the number of the people which would lose their jobs in case a centralized coal power plant is decommissioned . For a reference case is taken "Bobov dol" power plant in which are occupied 520 persons and the annual electricity production in 2011 was about 2.5 TWh. Considering the 8.05 TWh/a electricity generation of the " Alternative 1" it means about 1 500 people employed in coal power plants would lose their in case of decommission jobs if the it is assumed the figure from "Bobov dol" plant.

4.7 Reduction of GHG emissions

The emissions of GHG and the potential of the three alternatives for reduction is the third main criterion to assess them from socioeconomic point of view.

Annual emissions	Alternative 1	Alternative 2	Alternative 3
SO_2 [t]	1 236	586	-
NOx [t]	34 776	19 240	5 474
CH_4 [t]	20 801	24 090	27 048
N_2O [t]	32	36	39
CO_2 e [t]	446 807	516 928	579 986

Table 9. The annual emissions of the three alternatives (Agency and Energinet 2010)**.**

The comparison of the emissions for the three alternatives based on the used fuel annually in Table 9 shows that the waste/energy crops alternative has lowest GHG annual emissions considering the total of 446 807 tCO_2e. GHG emissions of "Alternative 1" are with about 130 000 tCO_2e less than the "Alternative 3" which is the greatest emitter of GHG amongst the three alternatives. The GHG emissions which would be emitted in the case of "Alternative 2" is implemented are 516 928 tCO_2e which is with about 70 000 tCO_2e more than "Alternative 1" but still less with 63 000 tCO_2e than the NG alternative.

However, considering the emissions of SO_2 and NOx "Alternative 1" is the biggest emitter. In the situation of "Alternative 1" there are more than twice SO_2 emissions than for "Alternative 2" whilst in case of "Alternative 3" there are no SO_2. NOx emissions of waste/energy crops alternative are more than six times than NG while waste/NG alternative emits about four times more than NG one.

In order to show what would be the potential reduction of GHG from the implementation of each of the three alternatives a comparison with existing coal based CHP plant “Bobov dol” is made (Table 10). The plant is a typical example of Bulgarian base load coal power plants it has an installed capacity of 420 MWe (Petrov 2011). If the same plant was able to utilize the same amount of fuel as the three alternatives it would have had GHG emissions of 5 755 832 tCO_2e.

Annual emissions	Alternative 1	Alternative 2	Alternative 3	Reference
CO_2 eq. [t]	446 807	516 928	579 986	5 755 832
Reduction CO_2 e[t]	- 5 309 026	- 5 238 904	- 5 175 846	-

Table 10. The potential reduction of GHG for the three alternatives compared to a reference coal based power plant “Bobov dol” (Petrov 2011)**.**

It is natural that the biggest reduction would be if the “Alternative 1” is implemented because it has lowest emissions compared to the other two alternatives. What is important to be outlined is that even the NG alternative which has greatest GHG emissions amongst the three alternatives emits about ten times less than the amount which the “Bobov dol” coal power plant would emit. Only the GHG emissions are taken into account looking upon the emissions of the reference plant but there would be other atmospheric emissions as CO and SO_2 also ashes slags etc. therefore any of the three alternatives in terms of pollution as a result of an energy production would be far more preferable.

4.8 Sensitivity analysis

In regard of the assumptions made for the socioeconomic analysis of the three alternatives a sensitivity analysis is presented.

The sensitivity analysis considers import share of the investment costs as it is a crucial factor for the economy of the proposed alternatives. The change of the investment cost won’t change only the EIAC and consequently the EAC of the three alternatives but also would lead to a change of the GDV (Gross domestic value) of the three investments and therefore to variation of the employment effect.

It is assumed a 10% alteration of the import share of the investment costs. Change of the import share of the investment costs is made assuming a 10% increase in case there are not industrial companies in Bulgaria able to produce the part of those 10% in term of equipment. On the contrary a decrease of 10% of the import share is proposed from the initially assumed 60% for the three alternatives.

If the changes of the import share of the investment cost is 10% it would lead to a fluctuation of the investment costs with 216 318 829 € in the situation of “Alternative 1” (Table 11). The fluctuation of the investment costs for “Alternative 2” would be232 798 616 €, for “Alternative 3 “ it would be 123 720 538 €. The change of the import share of the investment costs would cause an alteration of EAIC and EAC of 6 489 565 € for waste/energy crops alternative, 6 983 958 € for waste/NG and 3 171 616 € for NG alternative.

	Alternative 1	Alternative 2	Alternative 3
Fluctuation of the Investment costs [€]	216 318 829	232 798 616	123 720 538
Fluctuation of the EAIC and EAC [€/a]	6 489 565	6 983 958	3 711 616

Table 11. Fluctuation of the EIAC and EAC of every 10% change of the import share of the investment costs.

Considering the variation of the investment costs and EAIC and EAC as a result of the change of the import share of the investment costs of the three alternatives with 10% then the following results on Figure 10 and Table 12 can be seen in two assumed cases if the import share is increased from 60% to 70% and decreased from 60% to 50%.

The investment costs to the Bulgarian society for the implementation of "Alternative 1" if the import share is 50% would be 1 081 594 143 €, in case the import share is 70% than the costs significantly increased to 1 514 231 800 €. The costs for implementation of "Alternative 2" accounting import share of 50% would be 1 163 993 080 € and 1 629 590 312 € in case the import share is 70%.

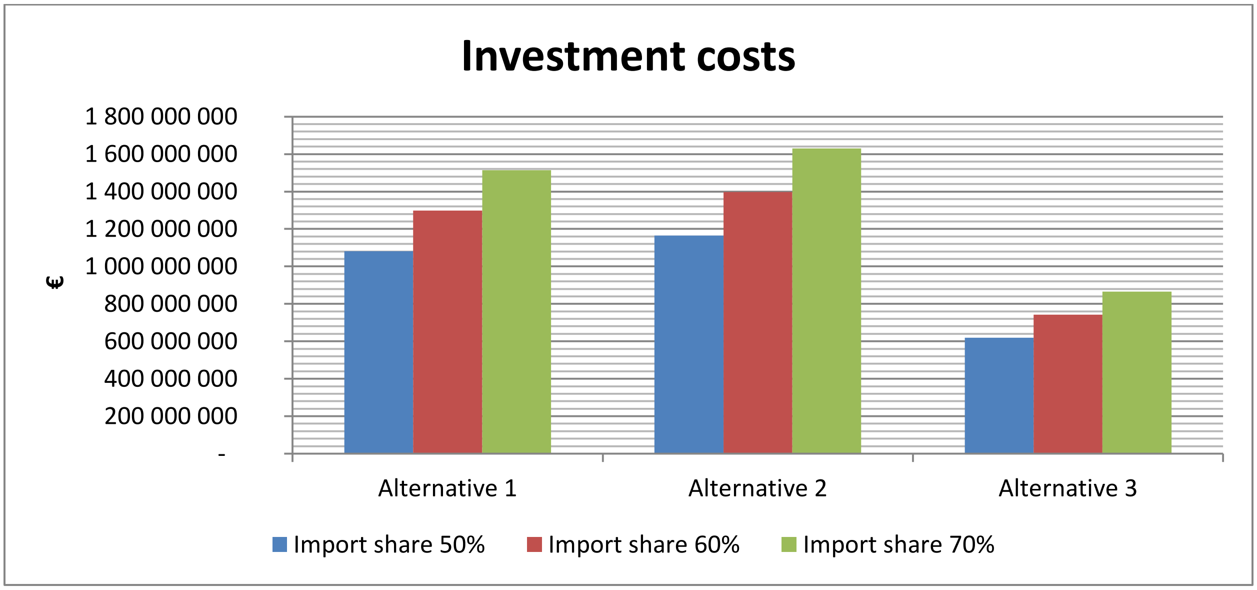


Figure 10. Investment costs of the three alternatives with import share of 50%, 60% and 70% (Agency and Energinet 2010)**.**

Alternative 1	Import share 50%	Import share 60%	Import share 70%
EAIC €/a	32 447 822	38 937 387	45 426 952
EAC €/a	240 763 292	247 252 857	253 742 421
EAIC share in EAC	13%	16%	18%
Alternative 2			
EAIC €/a	34 919 791	41 903 749	48 887 708
EAC €/a	469 870 361	476 854 319	483 838 278
EAIC share in EAC	7%	9%	10%
Alternative 3			
EAIC €/a	18 558 079	22 269 695	25 981 311

EAC €/a	825 095 880	828 807 496	832 519 112
EAIC share in EAC	2%	3%	3%

Table 12. The EAIC and EAC of the three alternatives if there is an import share of the investment costs of50%, 60% and 70%. The share of the EAIC in EAC.

Alternative 3" would have investment costs of 618 602 689 € in a situation with import share of 50% while the investment costs would rise considerably to 618 602 689 € if the import share is 70%.

Table 12 represents EAIC and EAC of the three alternatives if the assumed for the socioeconomic calculations 60% import share of the investment costs is increased to 70% or decreased to 50%.

To estimate the significance of 10% fluctuation of the import share of the investment cost over the EAC which is the main criterion for the evaluation of the economic effectiveness of the three alternatives it is important first to be seen the share of the EAIC in EAC. The share of the EAIC in EAC is lowest for the "Alternative 3", it increases from 2% to 3% according to the import share of the investment costs is 50%,60% or 70%(Table 12). The share of EAIC in the EAC for "Alternative 3" vary from 7%,9% to 10% depending on the partition of the import share of the investment costs. The part of the EAIC in EAC in the case of "Alternative 3" increases gradually from 13% to 18% in accordance to the respective import share of 50% and 70%. Comparing the part of EAIC in EAC of the three alternatives can be concluded that the value of the import share of the investment costs is greatest in case of waste/energy crops alternative and in specific when the import share is assumed to be 70%. On the contrary the less weight over the EAC is in the case of NG alternative which is due to the very high O&M and particularly the high fuel costs. Therefore if the "Alternative 1" is to be implemented in Bulgaria it must be considered the significance of the import share of the investment costs over EAC.

The balance between the domestic and import share of the investment expenses is not only influencing the costs in general but also have a direct impact over the employment created by the three alternatives. First is calculated the fluctuations in the GDV, employed persons and man years in case of 10% variation of the domestic share. As Table 13 displays the biggest fluctuation is in the case of "Alternative 2" , less are they for "Alternative 1" and in the least for "Alternative 3".

	Alternative 1	Alternative 2	Alternative 3
Fluctuation of the GDV with €	216 318 829	232 798 616	123 720 538
Fluctuation of employed persons *	3 012	3 665	1 477
Fluctuation Employment man years *	860 691	1 047 171	49 889

Table 13. The influence of 10% change of the domestic share of the investment costs over employment indicators.*For the lifetime of the investment

Alternative 1	Domestic share 50%	Domestic share 40%	Domestic share 30%
Gross domestic value €	1 081 594 143	865 275 314	648 956 486
Total employed persons *	22 494	19 482	15 071
Employment man years *	6 426 989	5 566 298	4 306 076
Alternative 2			
Gross domestic value €	1 100 940 435	931 194 464	698 395 848
Total employed persons *	21 058	17 393	13 728
Employment man years *	6 016 515	4 969 344	3 922 173
Alternative 3			
Gross domestic value €	618 602 689	494 882 151	371 161 613
Total employed persons *	8 162	6 685	5 208
Employment man years *	2 914 974	1 910 057	1 860 169

Table 14. The employment effects in case of domestic share 50%,40% and 30% domestic share of the investment. *For the lifetime of the investment.

As it can be noticed on Table 14 the GDV of the investment and the employment grows gradually in dependency to the domestic share. The least employment it is in the case of 30% domestic share in the case of NG alternative. Highest employment is when the domestic share is 50% for the waste/energy crops alternative.

4.9 Conclusion

Relying on the above presented results and relate them to the organizational goals it can be concluded that waste/energy crops alternative is the one which can reduce the Bulgarian dependency on NG, it would have the most significant employment effect and it would lead to least GHG emissions in the most cost effective way from socioeconomic point of view.

If it is assumed that NG alternative is going to be implemented the assumed natural gas for the production of 8.05 TWh/a is 64 PJ or about 1 741 MCM. Considering the projected price for the energy plants of 0.4 €/Nm^3 it would result in about 749 million euros annually or about 15 billion euros for the period of 20 years. Therefore it can be concluded that in the regard to the reduction of the import of NG gas the implementation of waste /energy crops alternative would save about 15 billion euros fuel expenses from social economic point of view.

If the implementation of biogas potential in Bulgaria aims the replacement of 31.2 PJ/a NG used for the combined heat and power generation in 2010 then waste/energy crops alternative potential doubles that demand. Biogas production based only on waste feedstock excluding energy crops is assumed to have annual energy potential 30.5 PJ which almost covers the required 31.2 PJ annually.

The most important reason waste/energy crops alternative to be most cost effective from socioeconomic point of view is the reason that in its case there are no costs for fuel which leads to a way lower EAC. In the case of waste/energy crops alternative the employment effects are highest because the production of biogas would requires more persons per million euros than NG. The reason for the biogas to lead to most cost reduction is that it is CO_2 neutral fuel.

The waste/energy crops alternative represents the possible implementation of the assumed realizable potential for biogas production in Bulgaria. Therefore it can be concluded that according to the organizational goals the implementation of biogas in CHP plants in Bulgaria is socioeconomically feasible.

5. Discussion chapter

In the chapter are discussed the assumptions and delimitations of the study.

5.1 Assumptions and delimitations related to the estimation of the biogas resources

There are number of ambiguities when the potential of the biomasses for biogas production in Bulgaria is estimated.

Due to the lack of data when the potential from food industry and household waste to be defined, figures about the DM content which are relevant for other countries are incorporated. These figures might vary greatly in the Bulgarian conditions and consequently increase or decrease the biogas yield from the two types of waste.

A similar assumption is made with the choice of maize silage as a representative case of all energy crops. A main reason to choose maize is based on the energy input output figures from German cases because there is no such a data available for Bulgaria. The results for the German case might be different in the case of Bulgaria due to the climate conditions, soil fertility, cultivation practices etc.

In order the potential from energy crops to be estimated the amount of arable land is assumed taking into account the constraint fuel vs energy. Looking only into this constraint limits the objective estimation of the potential for biogas production from energy crops because there might be other dependencies which can also limit the amount of the arable land available for the dedicated cultivation of energy crops. Planning to use even 10% from the arable land of the country for energy crops instead for food production e.g. would probably decrease the export of agricultural production and respectively increase the import which consequently might influence negatively the balance of payments.

The estimation of the potential from animal manure is based on the number of animals not on the collected manure. Calculating the amount of the manure based only on the potential average daily amounts per animal cannot display the realistic total amounts of manure. For instance in the case of cattle which has the biggest potential amongst the considered animals it is not known the number of grazing animals and the number of days during the year which could minimize the assumed realizable potential. In the study is only considered the potential from manure but not from deep litter which also would alter the potential for biogas production from animal excreta.

In general for the estimation of the availability of the different biomasses for the AD process in the report are taken different constraints related to their competitive use but in most of the cases those constraints are based on assumptions instead on real figures. Due to the not equally available data the biomass resources are not equally presented in Chapter 3 e.g. only for the energy crops and animal manure there are maps which present their location.

The definition of the amount of the total and assumed realizable potential is based on the individual yields of the different biomasses and it is not considered that in the co-digestion process the biogas yields might differ according to the type and the proportion of the different biomasses.

5.2 Assumptions and delimitations related to the socioeconomic feasibility study

Not the only but the main purpose for the realization of biogas project is justified by its application of for energy production. In the present study the utilization of vast amount of biogas is assumed. The assumed annual electricity production from implementation of the assumed realizable potential for biogas production is 8.05 TWh which would be about 17% from the total electricity generation of 46.6 in 2010. It is assumed that that electricity will be generated by many CHP plants with installed capacity around 3 MWe. That itself would lead to a significant decentralization of the electricity system in Bulgaria. Therefore, the potential of the electricity system to be decentralized need to be taken into account when a socioeconomic feasibility study is applied. There is also a need the consequences for the energy system to be analyzed (Hvelplund 1998). However, the report does not consider the consequences from the decentralization for the electricity or for the energy system in general. Another important delimitation of the report relates to the heat production of the biogas use which is expected to be 8.05 TWh annually. The heat consumption in Bulgaria for 2010 was 11.4 TWh (Ministry of Economy,Energy and Tourism 2012). In the report is not considered the development of the heat demand for the period between 2010 and 2030 and the particular utilization of the heat produced from biogas application in CHP. Not considering the implications from partial decentralization for the energy system limits the aim of the study to give an overall picture of socioeconomic impacts caused by the implementation of the assumed realizable potential for biogas production in Bulgaria.

The alternatives proposed in the feasibility study are set in order to be comparable thus same electrical, thermal efficiencies and also similar installed capacities are assumed for the three alternatives. It must be acknowledged that this prevents the advantage for the NG to be utilized in bigger plants which would have higher efficiencies and lower costs due to the economy of scale. NG gas plants could be bigger since they are not bound to the limits of the fuel.

The 300 t/d plant capacity is chosen for the biogas production of the alternatives. The assumption is made considering the 300 t/d plant is a centralized biogas plant with average capacity using the example from Denmark (Nielsen and K. Hjort-Gregersen 2002). However, it is not known whether that would be the most representative case for Bulgaria since in the study is not incorporated the location of the considered various biomasses.

Another important assumption relates to the value of the different monetized benefits accounted in the report. The figures are taken from ”Socio-economic Analysis of Centralized Biogas Plants” which reflects over the Danish case and the values of the benefits are slightly lowered considering the Bulgarian conditions.

6. Conclusion

The chapter summarizes the findings made in the report in order to answer to the two research questions and enlightens the potential next steps for the implementation of biogas technology in Bulgaria.

Taking into consideration current problems such as GHG emissions, energy dependency, waste management and high unemployment rate the aim of the study is to focus on the impacts for their solution caused by the possible implementation of biogas and its utilization in CHP in Bulgaria. Therefore the main research question was outlined:

Is the implementation of the potential for biogas production and its utilization in CHP socioeconomically feasible for Bulgaria?

The implementation of the potential for biogas in Bulgaria obliges first the potential to be estimated. Thus the secondary research question is specified:

What are the main biomass resources and what is their potential for biogas production in Bulgaria?

As it seen from Table 1 the highest potential of 33.9 PJ for has energy crops considering the potential from maize silage. The second high with 17 PJ is for the straw from and residues. The third is the potential from animal manure with 11.1 PJ. A way less potential from the first three have household waste with 1.9 PJ followed by sewage sludge with 0.9 PJ whilst least potential for biogas production has food industry waste with 0.5 PJ. The total assumed as realizable potential from all biomass is 65.3 PJ.

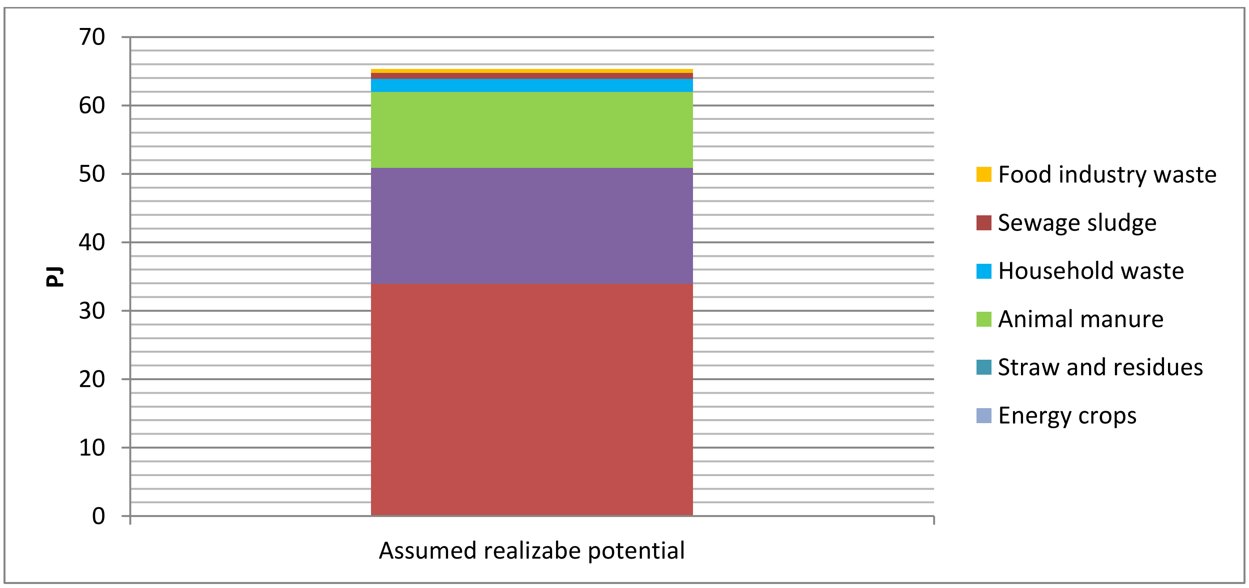


Figure 1. Assumed realizable potential from main biomass sources in Bulgaria.

Following step in the report was socioeconomic feasibility to be applied in order to answer the main research question.

Based on the assumed realizable potential (excluding sewage sludge) three mutually comparable alternatives were proposed. First alternative is related to the implementation of biogas potential from waste and energy crops. Second is based on the utilization of waste and imported NG which replaces the potential of the energy crops. The third alternative was established considering there is not biogas but instead imported NG is implemented.

First important indicator for the assessment of the three alternatives is their costs for the Bulgarian society. The other three criteria are based on their potential contribution to decrease fuel imports, create jobs and lead to reduction of the GHG.

Based on the above displayed criteria and the results from the applied methods to assess the alternatives it was concluded that waste/energy crops alternative has lowest socioeconomic costs, greatest employment effects and emits least GHG. Considering that the waste/energy crops alternative represents the implementation of the assumed realizable potential in Bulgaria can be confirmed that the implementation of biogas production and its utilization in CHP plants in Bulgaria is feasible from socioeconomic point of view.

It can be also concluded that biogas is a versatile energy source from which utilization the only output is not only electricity and heat but also the digested biomass which is useful fertilizer. There are also numerous benefits from biogas production taking into consideration the waste as a feedstock for its production. Therefore, the planning of biogas plants should not only be based on energy demand but also on the need waste materials to be utilized and accounting also the potential benefits from the digested biomass.

The potential next steps in regard to the implementation of large scale biogas production in Bulgaria would be a business economic feasibility study of the proposed alternative. It is required because often project can be feasible from socioeconomic point of view but not feasible from business economic view and vice versa (Hvelplund 1998). Another important step would be to define the potential of Bulgaria to implement that new for the country technology. It must be assessed the institutional potential, technical in terms of knowledge and organizational i.e. how the implementation would be supported in the early R&D and inception phases.

Reference list

Abbasi, Tasneem. 2012. *Biogas Energy / by Tasneem Abbasi, S.M. Tauseef, S.A. Abbasi*, edited by S. M. Tauseef, S. A. Abbasi and SpringerLink (Online service) New York, NY : Tasneem Abbasi.

Agency, Energy, Danish and Energinet. 2010*. Technology Data for Energy Plants*.

Al Seadi, Teodorita, Dominik Rutz, and Rainer Janssen. 2008. *Biogas Handbook* University of Southern Denmark.

Banks, Charles. 2009*. Optimization of Anaerobic Digestion*.

Braun, Rudolf and Peter Weiland. 2010*. Biogas from Energy Crop Digestion*. http://www.iea-biogas.net/_download/publi-task37/energycrop_def_Low_Res.pdf.

Bulatom, NGO. 2013*. Bulgarian Electricity System and the Need of a New Nuclear Power Plant*.

Commission Regulatory, State,Energy,Water. , http://www.dker.bg/otrasyl.php?OID=71.

Commission, European. 2012*. EU Energy in Figures*.

———. . 2003*. External Costs,Research Results on Socio-Environmental Damages due to Electricity and Transport*.

Deublein, Dieter (ed). 2008. *Biogas from Waste and Renewable Resources : An Introduction*, edited by Dieter Deublein, Angelika Steinhauser Weinheim : Wiley-VCH.

DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the Promotion of the use of Energy from Renewable Sources and Amending and Subsequently Repealing Directives 2001/77/EC and 2003/30/EC, (2009): .

Eurostat. "GDP Per Capita Varied by One to Six Across the Member States in 2011." EU Commission, http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/2-13122012-AP/EN/2-13122012-AP-EN.PDF.

Federal Environment Agency. 2010. "Sustainable Production through Innovation, Biogas Production in Germany." .

Holm Nielsen, Jens Bo, Piotr Oleskowicz-Popiel, and Teodorita Al Seadi. 2007. "15th European Biomass Conference & Exhibition from Research to Market Deployment." .

Holm-Nielsen, J., T. Al Seadi, and P. Oleskowicz-Popiel. "The Future of Anaerobic Digestion and Biogas Utilization." *Bioresource Technology* 100 (22): 5478-5484.

Hutňan, M., A. Kalina , I. Bodík, T. Petheöová, and Š. Štifner. "Start-Up and Operation of the First Biogas Station for Agricultural Crops in the Slovak Republic ." *2009*.

Hvelplund, Frede. 1998. "Feasibility Studies and Public Regulation in a Market Economy : The Implementation of Environmental Objectives and Technological Change in the Energy Sector." *Feasibility Studies and Public Regulation in a Market Economy : The Implementation of Environmental Objectives and Technological Change in the Energy Sector*.

International, Energy, Agency. *Energy Technology Perspectives*.

Jørgensen, Peter Jacob. 2009. *Biogas - Green Energy*: Aarhus University.

Kørnøv, Lone. 2007. *Tools for Sustainable Development*, edited by Mikkel Thrane, Arne Remmen, Henrik Lund and Lone Kørnøv Aalborg : Aalborg Universitetsforlag.

Lovrenchec, Larisa. "Highlights of Socio-Economic Impacts from Biogas in 28 Target Regions ." *2010*.

Lund, Henrik. 2010. *Renewable Energy Systems : The Choice and Modeling of 100% Renewable Solutions* Burlington, Mas : Academic Press.

Ministry of Economy,Energy and Tourism. *Energy Strategy of Republic of Bulgaria Till 2020*.

———. 2009. "National Long Term Programme to Support the use of Biomass 2008-2020." .

———. . 2012. *Report about the Condition and Development of Energy Sector in Bulgaria*.

Ministry of Food and Agriculture. 2011. *Annual Report about Current Condition and Development of Agricultural Sector*. http://www.mzh.government.bg/MZH/Libraries/%D0%9E%D1%84_%D0%94%D0%BE%D0%BA_-_%D0%90%D0%B3%D1%80%D0%B0%D1%80%D0%B5%D0%BD_%D0%B4%D0%BE%D0%BA%D0%BB%D0%B0%D0%B4/Agraren_Doklad_2011.sflb.ashx: Ministry of Food and Agriculture.

Ministry of Labour and Social Policy. 2011. *National Strategy for Demographic Development of Population of Republic of Bulgaria*.

Ministry of Water and Environment. 2010. *National Strategic Plan for Phased Decrease of Biodegradable Disposed Waste*.

National Statistical Institute. 2012. *Waste by Industry by Type*.

———. "ОСНОВНИ РЕЗУЛТАТИ ОТ НАБЛЮДЕНИЕТО НА РАБОТНАТА СИЛА ПРЕЗ 2012 ГОДИНА.", http://www.nsi.bg/EPDOCS/RabSila2012_DIVD76J.pdf.

National Statistical Institute, Energy. "Energy.", http://www.nsi.bg/otrasal-metodologia.php?otr=30.

Nielsen, L. H. and K. K. Hjort-Gregersen. 2002. *Socio-Economic Analysis of Centralised Biogas Plants*.

Olesen, Boye,Gunnar and Emil Bedi. 2006. *Guideline for Estimation ofRenewable Energy Potentials,Barriers and Effects*.

Petrov, Petur. 2011. *Annual Report of CCHP Bobov Dol*.

RES, Made i. G. "Http://www.Renewables-made-in-Germany.com/en/renewables-made-in-Germany-start/biogas/biogas/market-Development.Html;".

Stoyanov, Todor. 2013. *Challanges in Implementing Biogas Plants in Bulgaria*. Aalborg.

Sustainable Energy Development Agency (SEDA). 2013. "Production of Energy from RES.".