Selected technical and socio – economic impacts of solid biomass utilisation in Polish power system in 2020

Master's thesis

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Master Programme in Sustainable Energy Planning and Management
(Group SEPM4-2011-10), June 2011

This thesis is dedicated to my parents,

for their love and support

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Abstract:
Polish energy sector, heavily dependent on hard coal and lignite, faces challenges connected with old plants struggling to comply with environmental requirements and the obligation to reach 15% of the country's final energy consumption from renewable sources by 2020. Among the sources with the highest potential is solid biomass, but the issue of its utilisation in Poland is controversial and linked to many stakeholder interests.
This thesis investigates the aspects of underdevelopment of available solid biomass resources for electricity generation and their inefficient use in old plants, whilst analysing the technical, political and institutional conditions of the biomass usage in Poland and considering selected socio-economic benefits.
Review of potentials, electricity costs calculations and Balmorel modelling tool are used to design and present a 2020 power system scenario and two alternatives.
The results of each of the scenario are compared in relation to identified goals of the research. A socio-economic analysis is conducted and barriers to potential increased biomass implementation are demonstrated.
Conclusions and recommendations for further work are presented.

Preface

This thesis was prepared as part of a requirements for achieving Master's degree in Sustainable Energy Planning and Management course at Aalborg University. It was written with support of the EA Energy Analyses in Copenhagen from 1st February to 16th June 2011.

In this report, the literature references are marked with the author name and the year of publication in brackets, in accordance with the Chicago reference style. The appendices, containing supplementary materials, are assigned each with a capital letter and referenced in the document. Figures and tables are numbered in format x.y, where x stands for the chapter number and y for the number of the item.

I would like to express special thanks to my supervisors, Frede Hvelplund from Aalborg University and Kaare Sandholt from EA Energy Analyses for their continuous support and ideas provided during the research.

The time spent during writing a Master's thesis at EA has been an extraordinarily valuable and fruitful experience. Therefore I would like to thank to all the other employees and students at EA for creating a friendly atmosphere.

Copenhagen, 16th June 2011

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Sara Ben Amer

List of abbreviations

ERO	Energy Regulatory Office
EU	European Union
EUR	European currency, euro
ha	hectare (s)-unit of area
ktoe	Kilotonnes of oil equivalent
Mt	Megatonnes
MtOE	Megatonnes of oil equivalent
NREAP	National Renewable Energy Action Plan
NFEPWM	National Fund for Environmental Protection and Water Management
PLN	Polish currency, *złoty*
RES	renewable energy sources
t	tonnes
toe	Tonnes of oil equivalent
TSO	Transmission System's Operator
TWh	Terawatt hour

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1 Introduction

The introduction will provide an outline of background and context for analysis in the thesis. In particular, a general overview of the Polish energy system and future prospects in view of European commitments will be depicted. It will also generally touch upon issues connected with biomass in Poland, as well as a review of the current trends in this sector. Finally, the introduction will name the specific issues in focus of the thesis that will enable a formulation of the research question, followed by supporting questions.

1.1 General background

Poland, a former member of the Eastern bloc, but also, since 2004 a rapidly developing EU Member State, has long been dependent on hard coal and lignite as its energy sources. Large power plants, mainly from 60s' and 70s', as well as mines, have been indestructible symbols of the energy landscape in the country, especially valued in the past time of economy based on heavy industry rather than services.

As of 2009, almost 90% of the primary energy production in Poland came from hard coal and lignite (Eurostat 2008). While the EU requirements are taken more and more seriously, it is acknowledged that the potential of other abundant natural source in Poland, biomass, is not fully used in a way it could support the CO_2 emission reductions and development of new investments.

Although a possibility of a new industry that could be created thanks to biomass cultivation exists, its full advancements is still underway. However, the sooner this idea will be realised within Poland, the better possibility for developing expertise and high domestic share of investments. The section 1.2 that follows contains the problem formulation and research question that were identified to guide investigation within this thesis.

1.2 Problem formulation and research question

Currently, Polish energy sector, heavily dependent on hard coal and lignite, faces a number of challenges. These are connected with old capacities that need to be decommissioned due to not complying with future environmental requirements. Moreover, accordingly with the EU's Climate package, by 2020 Poland is obliged to reach 15% of its final energy consumption from renewable sources. Among the two most promising sources is biomass. However, the issue of biomass usage in Poland is controversial and linked to many stakeholder interests. Currently, the majority of the biomass resources used by the energy sector come from forests that as of 2008 covered 29% of the area of Poland. Such usage causes controversies among NGOs such as Greenpeace and WWF, because it is deemed by them to cause deforestation in Poland in the future. The paper and furniture industries, for which the wood is essential, are also against the ever increasing use of forest-based wood by energy generators, because it causes raw biomass prices to rise significantly. Additionally, at the moment, large energy companies in Poland are more and more investing in co-firing retrofitting equipment in their power boilers. However, this causes supposedly inefficient and unsustainable use of available biomass, which is transported for long distances to feed large boilers, and should not be continued.

Nevertheless, a number of solutions could be applied to improve the current situation in view of future EU and national commitments. Except for more sustainable forest management practice, a significant amount of biomass could be provided by straw waste and energy crop plantations, even without threatening food production in Poland. Moreover, a number of efficient, new CHP plants could be implemented, allowing more reasonable use of the renewable source.

In the scope of the thesis, the following problems will be analysed in more detail:

a) Inefficient use of biomass resources in old plants
b) Underdevelopment of usage of energy crops and straw for electricity generation

Thus, in order to analyse the aforementioned problems and come up with possible solutions, a research question has been developed:

How can the technical, political and institutional conditions of the biomass usage in Poland be changed in a way that solves the aforementioned problems a and b and allows greater socio-economic benefit, namely employment generation and state budget revenues?

As an approach for resolving the problems mentioned above, the main research question is accompanied by a set of more specific questions:

- What is the potential of biomass for energy purposes in Poland, given the resources are used in efficient plants and new biomass sources are developed?
- How can biomass be used in highly efficient, new CHPs to allow CO_2 reductions and result in increasing employment levels and improving state budget in 2020?
- What are the political and institutional conditions of biomass implementation in Poland and how should they be changed to obtain a development of new resources and more efficient use of biomass?

The thesis consists of ten chapters and is structured as follows:

Chapter 1 provides an introduction to the issues covered in the thesis, the problem formulation and research question.

Chapter 2 presents the theoretical approach and methodology to conducted research and analysis.

Chapter 3 forms a background to Poland, covering geopolitical aspects, spatial planning system, as well as employment, and state budget description.

Chapter 4 demonstrates results of a literature review of the biomass potential in Poland, consisting of forest biomass, straw and energy crops. It also touches upon current problems in the sector that are in the scope of this project, namely inefficient use of biomass in old plants and untapped potential of energy crops, as well as straw. The biomass market in Poland is also shortly described.

Chapter 5 aims at analysing available biomass technologies and identifying the most optimal for Poland in 2020, through calculations of electricity costs.

Chapter 6 presents the current 2010 power system, as well as three scenarios for 2020: "Business as usual", "Efficient business as usual" and "New biomass", generated through the use of the Balmorel software model. The chapter also provides an analysis of the scenarios based on the selected goals.

Chapter 7 has an aim of presenting the socio – economic consequences of scenarios, namely employment and state budget improvements.

Chapter 8 presents the structure and policy in the Polish biomass sector and implementation barriers for increased utilisation of solid biomass in the system.

Chapter 9 provides conclusions and recommendations.

Chapter 10 is bibliography of the thesis.

2 Theoretical approach and methodology

This chapter will discuss the theoretical approach and methodology used in the thesis. The theoretical approach is represented graphically in the subchapter 2.1 and divided into technological, institutional and political. In the subchapter 2.2 a general overview of methodology will be presented, followed by the structure of the report. Moreover, the specific methods used in the thesis will be described in the subchapters to follow, as well limitations of the thesis.

2.1 Theoretical approach

The theoretical approach can be defined as a theory supporting different parts of the interdisciplinary report, a "roadmap" in order to reach an answer to the research question, through using methodology discussed in the subchapter 2.2. A figure representing different types of theoretical approach applied and how they interplay together will be shown.

The theoretical approach, depicted in the figure 2.1 below is understood as the theory supporting each part of the thesis. In the picture, the large rectangle is meant to represent the boundaries of Poland, while the EU is set aside as an influencing factor. The figure sets out the most relevant theory components to allow for a comprehensive analysis to be undertaken in order to come up with the solutions to the formulated problem. The key elements are: goals, alternative technological scenarios, institutional conditions and the political process.

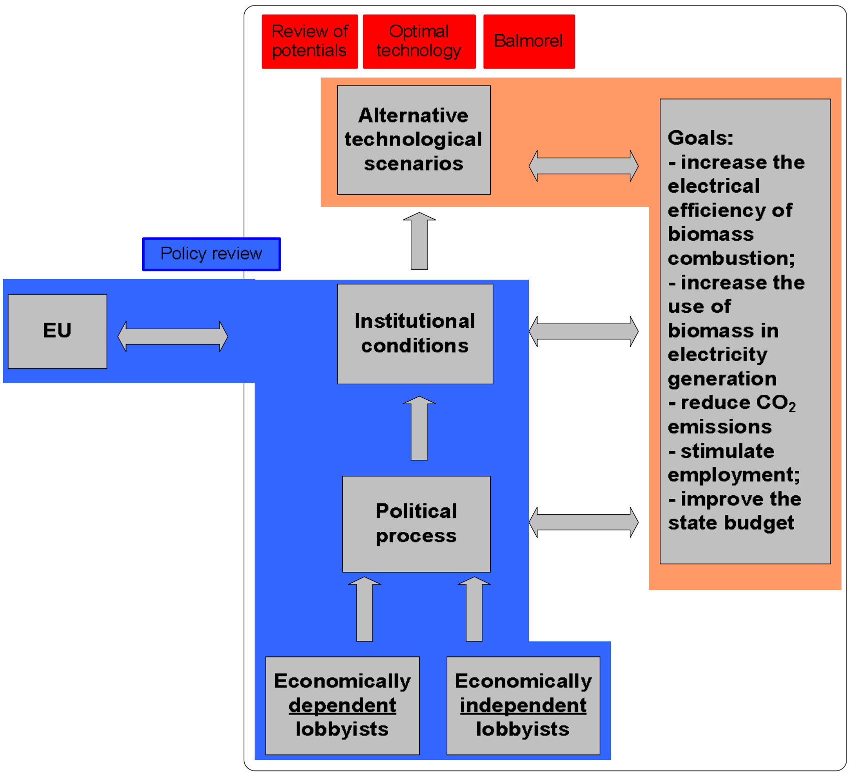


Figure 2.1 General theoretical approach of the thesis

Additionally, the figure appears at the beginning of each chapter, with relevant components highlighted so as to inform the reader where the current focus is. The selected goals shown in the figure 2.1 are considered to be the problems identified earlier in connection with problem formulation and research question. The goals consist of both technical goals (increase the electrical efficiency of biomass combustion, increase the potential of energy crops, straw and forest biomass, reduce CO_2 emissions) and socio-economic goals (stimulate employment and increase the state budget).

As it can be acknowledged from the research question, as well as goals identified, this thesis has an interdisciplinary character and touches upon multitude of aspects. In fact, it does have some pilot - study features, in terms that it adopts a more general research approach in order to venture into most important issues (Van Teijlingen and Hundley 2001). This approach may be regarded as general, but it is also beneficial, because it allows having a broader and fuller perspective and understanding more about different complex and interdependent issues, which if often the case in the energy sector.

However, such an approach also means that different delimitations had to be made, mentioned in the section 2.2.5. Although all the steps described in the theoretical approach are accomplished, it was not possible to always go into detailed analysis, so some secure and less secure results and conclusions were obtained, which can be further seen in chapter 9.

2.1.1 Technical theoretical approach

The technical theoretical approach corresponds with the alternative technological scenarios in the figure 2.1. In order to create those, a review of biomass potentials was conducted in the chapter 4, followed by optimal technology choice in the chapter 5 and Balmorel scenarios in the chapter 6. The scenarios result in achieving some of the goals of the thesis, namely: electricity generation from biomass, electrical efficiency of biomass units and CO_2 emission reductions. The modelling outcome is also a basis for calculating the socio – economic goals: employment stimulation and improvements in the state budget.

2.1.2 Institutional theoretical approach

The institutional theoretical approach encompasses aspects such as legislation and support schemes, but it is very often intertwined with the political approach, for example in the background information on legislation and political administration in Poland, presented in the chapter 3 or in the analysis provided in chapter 7. Moreover, the calculation results provided in chapter 7, concerning employment and trade balance are also identified as objectives to be researched.

2.1.3 Political theoretical approach

The political theoretical approach aims at researching the openness in public administration and the relations between actors that are not a result of the institutional relations. It corresponds mainly with the chapter 8, where the global, macro - and microstructure of the biomass sector are analysed. This approach has also connections with the institutional approach, in the chapter 3 and 7. It serves mainly identifying the dependencies in the biomass sector and the barriers that could undermine achieving the goals of the thesis.

2.2 Methodology

This section will demonstrate an overview of the methodology applied in the thesis and a general description of each method, namely literature review, electricity costs calculations and Balmorel model. Furthermore, the resulting structure of the report will be presented, including a short description of the content of each chapter.

2.2.1 Overview of methodology

The methodology used in the thesis integrates both qualitative and quantitative research methods in order to achieve a comprehensive understanding of Polish energy system and the current and prospective role of biomass in it. The research is done with an interdisciplinary approach that takes into consideration the technical and socio-economic aspects, allowing a multi – aspect, but also general, analysis.

First, an introduction of the current problems connected with biomass implementation in Poland is provided, thanks to literature review and data collection. Another use of the data collection is to form a basis for analysing costs of electricity of available biomass technologies, which is conducted through calculations in a spreadsheet. Next, the biomass technologies are applied as a choice of investments for Balmorel tool, which is made in the modelled scenarios. The optimal investment selection will be checked against choice made earlier in electricity cost calculation in chapter 5. Then, the effects of scenarios with regards to increased biomass potential, electricity efficiency and levels of CO_2 emissions will be analysed, as well as employment creation and state budget revenue. This will be followed by identifying the structure in the biomass sector and its main actors and the technological, political and institutional implementation barriers and conditions for increased biomass utilisation. Finally, the conclusion and recommendations, concerning technological, political and institutional aspects, are provided.

2.2.2 Literature review

The literature review in the thesis helps to define and describe important issues connected with the research question. It is focused on the following issues: geopolitical description of Poland, biomass potentials and developing biomass market in Poland, as well as structure and policy in the Polish biomass sector. The type of literature used include: books, articles, websites and documents from internet.

2.2.3 Electricity cost calculations

At the moment, a number of biomass technologies are available in the market. Thus, in order to choose the most economically feasible solution for the Polish electricity and heat system in the relatively short term perspective of year 2020, a simplified cost estimation of generating energy from new biomass technologies is done. The general methodology for calculations is presented below:

Cost of electricity [€/MWh] = annual investment [€/MWh] + annual fuel costs [€/MWh] + annual O&M costs [€/MWh] - heat income [€/MWh]

Out of all biomass power and heat technologies, an optimal is identified, based on cost and electricity efficiency. Specific data used and assumptions are provided in the chapter 5.2. The technology choice conducted in the chapter 5 is checked against choice made by Balmorel's investment identification in chapter 6.

2.2.4 Balmorel model

The Balmorel tool enables to incorporate the data regarding current and future Polish electricity and heat system and model it according to the scenarios. The modelling tool is chosen in order to observe the technical influence of increasing and changing the usage pattern of biomass in the Polish power system with a focus on CHP plants. Specifically, it will allow seeing the changes in operation of different plants, the overall efficiency of the system and CO_2 emissions. It will also serve the socioeconomic analysis in terms of investments; the latter needed to calculate the employment benefit.

In total, four scenarios will be modelled. First scenario will represent the 2010 electricity system, second the reference scenario "Business As Usual (BAU) 2020", third "Efficient BAU 2020" scenario fourth the "New biomass 2020 "scenario.

2.2.4.1 Structure of the Balmorel model system

The Balmorel model system consists of four main elements: **data** (input), **model**, **solver** and **results** (output) (EA Energy Analyses n.d.)

DATA

As the model of Poland comprises data on each unit in the system, it plays a very important role in Balmorel. Details in connection with the research are provided in the modelling in chapter 6, in appendices and below in table 2.1, where examples of types of necessary core input data for Balmorel are shown.

Table 2.1 Examples of data for Balmorel

Data type	Examples of data needed
Energy generation technology	Electricity and district heat technologies
	Type of fuel used (e.g. coal, wood, straw, wind)
	Electrical and total efficiency
	C_v, C_b values (see: *Energy technologies* below)
	Amount of capacities installed and lifetime
	Investment, fixed and variable O&M costs
	Amount of full load hours, variability factors for intermittent sources
Geographically specific data on generation, distribution, full load hours etc.	Potentials and restrictions on fossil fuels and renewables
	Losses in electricity and heat distribution
Electricity and district heating demands	Annual electricity demands in regions and district heat demands in areas
Balmorel investments in generation capacity	Type of investment technology

Energy technologies

Four basic groups of energy generation and storage technologies in Balmorel are: thermal power technologies, storage, heat production and intermittent technologies. They are shown in the figure 2.2 below.

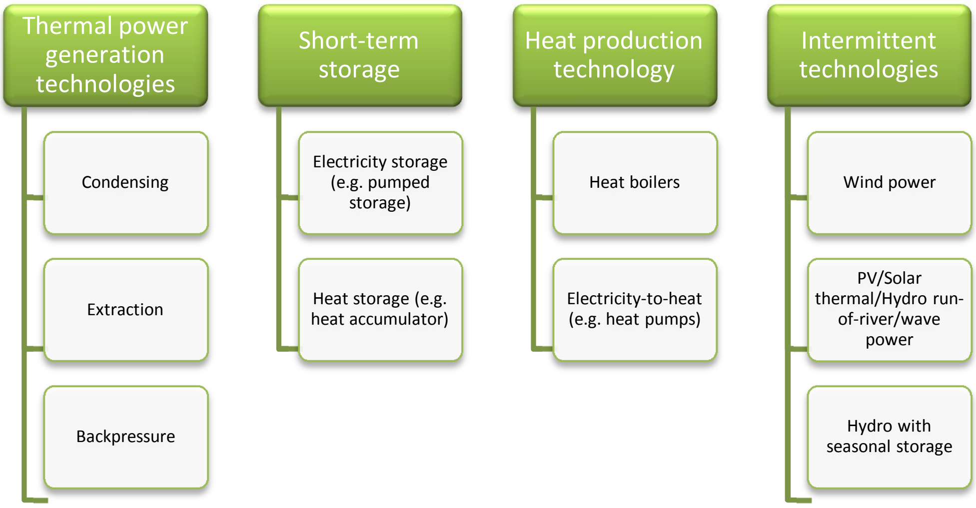


Figure 2.2 Basic energy technologies in Balmorel

Each thermal power generation unit (steam-driven power plant) represented in Balmorel is classified as condensing, extraction or backpressure type.

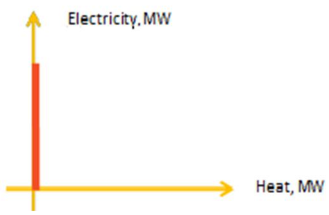


Figure 2.3 Condensing unit features (EA Energy Analyses n.d.)

Condensing units are those that produce only electricity (line marked in red), as it can be seen in the figure 2.3 on the left.

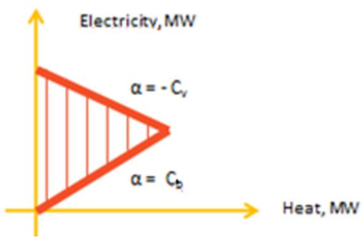
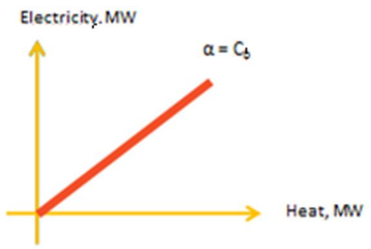


Figure 2.4 Extraction unit features (EA Energy Analyses n.d.)

Extraction units are usually large centralised cogeneration units that can switch between full CHP and full condensing mode. They are characterized by so-called C_b and C_v values represented in the figure 2.4 on the left.

The C_v value is a constant defined as the slope of the line representing the loss of electricity generation in relation to heat during a change from full condensing to full CHP mode, assuming constant fuel usage. The C_b value in extraction units equals to the minimum electricity production in relation to heat generation. It depends on electrical capacity, thermal capacity and C_v value as follows:

C_b *extraction = (net electrical capacity –* C_v *×thermal capacity)/thermal capacity*



Backpressure units (see figure 2.5) are usually smaller CHPs or combustion or Stirling engines. Here only the C_b value is calculated and is represented by the relation between electricity and heat production.

Figure 2.5 Backpressure unit features (EA Energy Analyses n.d.)

In backpressure plants, C_b is the ratio between electrical and thermal capacity:

C_b *backpressure = net electrical capacity/thermal capacity*

Finally, each unit can have fuel efficiency specified, which for condensing and backpressure units is calculated as follows:

Efficiency condensing/backpressure = net electrical capacity/available boiler power

For extraction units it is total efficiency, calculated as follows:

Efficiency extraction = (net electrical capacity + thermal capacity)/available boiler power

However, as the electrical efficiency was in the focus of the thesis, for each type of the biomass unit it was calculated as follows:

Electrical efficiency = net electrical capacity/available boiler power

Geographical layering

A geographical localisation of all production units and implied electricity supply and transmission and district heating supply is visible through Balmorel's country/region/area division feature. Countries consist of regions, which in turn consist of areas. Electricity can be transmitted to a certain extent or freely among all layers, depending on the transmission capacity set between regions. This allows the tool modelling of existing electricity bottlenecks in the system. Areas represent district heating and geographical situation of units. (EA Energy Analyses n.d.)

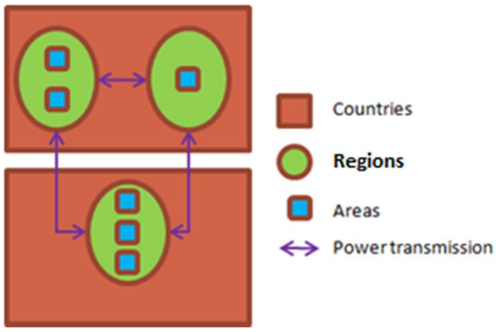


Figure 2.6 Geographical layering in Balmorel (EA Energy Analyses n.d.)

MODEL

The model itself requires implementation of the gathered data into a special modelling language called GAMS (General Algebraic Modelling System). The GAMS language is generally composed of: SETS; values indicated by SCALAR or PARAMETER; VARIABLES and EQUATIONS. Thus, a set of EQUATIONS form a MODEL (Ravn 2010). For the purpose of this thesis, only a limited knowledge of the modelling language was required due to the similarity of the type of Polish data required to the already existing in the model for the other Baltic region countries.

SOLVER

Solver is an algorithm that provides the modelling results. It aims at finding the least-cost solution for each time period and geographical element (overall and unit-specific) taking into consideration all entities in the model. In this process, certain criteria are applied, such as for example:

- Generation and consumption of electricity and heat
- Electricity transmission
- Emission, fuel and O&M costs

(EA Energy Analyses n.d.)

OUTPUT (RESULTS)

The output of Balmorel calculations is an extensive amount of results concerning all the values for which data was inserted and modelled. This output needs to be aggregated and filtered in order to reach the answer to the analysed problem. The types of results that can be yielded in a simulation are for example:

- Electricity and heat generation in each simulated time step
- Fuel consumption by specific units and overall in area/region/country
- Electricity sales
- Investments in new heat and electricity capacity, as well as storage facilities
- Emissions (CO_2, NO_x, SO_2)
- Efficiencies

(EA Energy Analyses n.d.)

2.2.5 Limitations

The limitations of the thesis, such as data collection or modelling limitations, will be described in this subchapter. Relevant issues not addressed in the report and the cause for non-inclusion will be depicted.

The report concerns solid biomass usage, with a focus on improving the efficiency and enhancing energy crops, forest wood and straw usage for energy purposes. The data on district heating is implemented in the model, but is not analysed. The target year is 2020. The technical aspects of biomass harvesting are not analysed, the energy generation technologies will be classified into groups containing range of performance and cost data for different technologies available in the market.

Regarding the modelling tool, Balmorel allows analysing a large number of values, which, considering the size of the interconnected systems and all the interdependencies, sometimes may cause some of the connections not to be represented in the MODEL or in the SOLUTION part. This certainly may cause limitations to the final result.

Another aspect is that Balmorel simulates a well-functioning market, which in real life conditions is not the case, especially in young EU members such as Poland, where electricity market still is, to some extent, managed by the state. This may cause discrepancies in terms of which units choose to operate, resulting in some inaccuracies for example in fuel mix, electricity prices and costs.

Moreover, the data regarding thermal power plants that form a vast majority of generation capacity was available for 2009. As 2010 was the modelled year, units were assumed to be the same as in 2009, with renewables capacity as of 2010.

Furthermore, as the technological scenarios in Balmorel were modelled in the so – called island mode, the Polish interconnections (to Germany, Sweden, Czech Republic, Slovakia, Ukraine and future connection to Lithuania) are not represented, because by the time of thesis finalisation the dataset for surrounding countries was not yet completed. This issue may cause some limitations in power flow representation in Poland in relation to the aforementioned countries. However, it is argued that such depiction does not have a major influence on the results, because in 2009 Poland exported around 2 TWh of electricity, which is approximately 1.5% of the overall energy generation in the state.

Table 2.2 Poland's electricity exchange in 2009 (ARE 2010)

Country	Poland's exchange balance (TWh)
Slovakia	2.28
Germany	-5.48
Czech Republic	6.74
Ukraine	-0.20
Sweden	-1.14
TOTAL	2.19

Moreover, currently the investment feature in Balmorel does not deal with the risk of fuel price change and any investments are only for the year that is stated, so investments in one year may prove less feasible in following years due to changed fuel prices.

Another limitation is that since only domestic biomass resources are taken into consideration, a possibility of imports from other countries is not analysed. If it was indeed, then the share of biomass could be larger from the one hand, but from the other, if the exports would also be taken into consideration, the overall number could be balanced, showing the number as if no restrictions on import/export were imposed.

2.3 Summary

This section will form a summary of the chapter 2.

The chapter 2 examined a theoretical approach and methodology of the thesis. The theoretical approach, divided into technological, institutional and political, forms the theory supporting different parts of the interdisciplinary report, a "roadmap" in order to reach an answer to the research question, through a means of methodology. A figure representing interdependencies between different types of theoretical approach was shown at the begininning of the chapter and will appear also in each of the subsequent chapters.

The research is conducted with an interdisciplinary approach that takes into consideration the technical and socio-economic aspects, allowing a more thorough analysis. The methodology used in the thesis consists of the specific methods, namely the literature review, calculations of the cost of electricity and Balmorel modelling tool. It integrates both qualitative and quantitative research methods in order to achieve a comprehensive understanding of Polish energy system and the current and prospective role of biomass in it.

The Balmorel model system consists of four main elements: data, model, solver and results. The basic energy generation and storage technology groups in Balmorel are: thermal power technologies, storage, heat production and intermittent technologies. A geographical localization of all production units and electricity supply and transmission and district heating supply is made possible through Balmorel's country/region/area division feature. Electricity can be transmitted to a certain extent or freely among all layers, depending on the transmission capacity set between regions. Areas represent district heating and geographical localization of units.

The Balmorel tool was chosen in order to observe the technical influence of increasing and changing the usage pattern of biomass in the Polish power system. It can also allow seeing the changes in operation of different plants, the overall efficiency of the system and each plant, as well as CO_2 emissions.

3 Background to Poland

This chapter will provide background description of Poland, namely a geographical description, the political administration and chosen socio-economic criteria, such as employment and state budget situation will be discussed further.

As it was mentioned in the theoretical approach chapter, the institutional and political approach is necessary to reach answers to formulated problems. The role of the chapter 3 is to provide sufficient background information on Poland concerning geographical location, political administration and spatial planning, as well as employment and state budget, in order to provide the reader with the context, as well as present information that will be used further in chapter 7, 8 and concluded in chapter 9. All the steps mentioned contribute to institutional and political parts of the theoretical approach, as is noticeable in the figure 3.1 below.

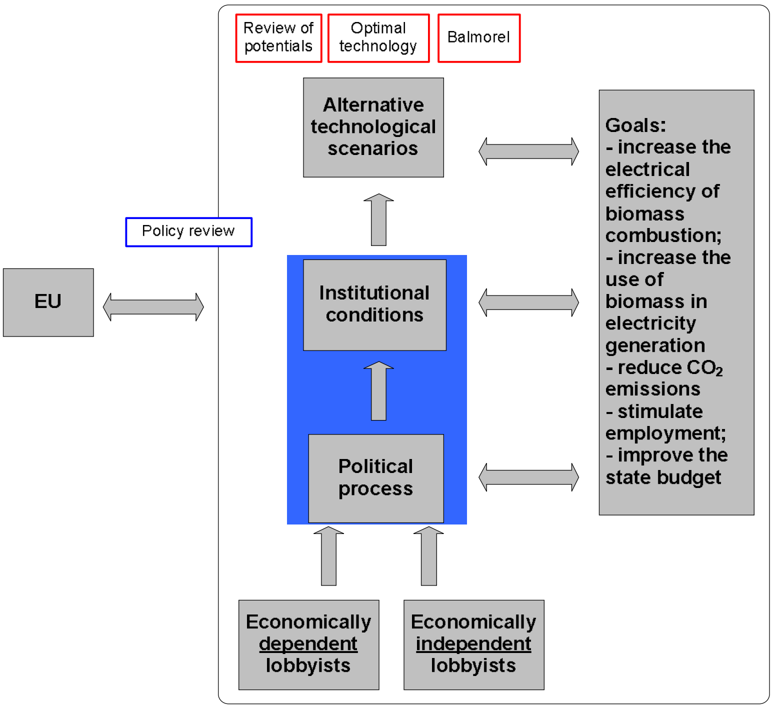


Figure 3.1 Theoretical approach to chapter 3

3.1 Geography, political administration and spatial planning

This subchapter will describe the geographical situation of Poland, the size and number of population. Moreover, the political administration system will be presented, including region/county/commune division and their responsibilities in view of supplying electricity and heat.

3.1.1 Geographical location

Poland is a country in Central Europe that borders with Germany, Czech Republic, Slovakia, Ukraine, Belarus, Lithuania and Kaliningrad Oblast (federal subject of Russia). Poland has a 440 – km long coastline along the Baltic Sea.

The country spreads on the area of 312 679 km^2 and has approximately 38.116 million inhabitants (as of June 2009). The capital Warsaw (Warszawa) is the largest city with a population of 1.72 million people, followed by Krakow, Lodz, Wroclaw and Poznan. 61% of the population lives in the urban areas, 39% in rural areas (Central Statistical Office of Poland 2010).

Figure 3.2 (on the left) Geographical situation of Poland (Wikipedia 2011a)

Figure 3.3 (on the right) Location of larger cities in Poland (Central Intelligence Agency 2011)

3.1.2 Political administration and spatial planning

Poland is a democratic country, with a president as the head of state, elected each five years (currently Bronisław Komorowski). The government consists of the Council of Ministers, led by a prime minister. A bicameral parliament consisting of a 460 – member lower house (*Sejm*) and a 100 – member Senate (*Senat*) is elected each four years (Wikipedia 2011a).

The territory of Poland is divided on three levels (see figure 3.4). First, provinces, are divided into counties, which are further divided into communes. Major cities usually have the status of both county and commune. Currently, Poland has 16 provinces, 379 counties and 2,479 communes. (Wikipedia 2011a), (Central Statistical Office of Poland 2010)

Figure 3.4 Administrative division (boundaries of provinces in black, counties – in red, communes – in green (Wikipedia 2011b))

The main regulative act concerning spatial planning and land management is the *Spatial planning act* from 2003 and administrative acts based on it. The technical conditions regarding buildings and municipal infrastructure are regulated by the *Building law* from 1994 and *Real estate management act* from 1997.

The obligations and tasks within spatial planning and land management are divided between central government and local governments on the level of provinces and communes. The central government prepares a *Strategy for development of Poland*, which touches upon the development in general. The Ministry of Regional Development is obliged to prepare a so-called *Concept of spatial development*; the local government on the level of province drafts a *Plan for spatial development* in its region. On the level of commune, a *Study on conditions and directions of spatial development* is conducted, setting rules for drafting so called *Local plans of spatial development* (administrative acts). In case the aforementioned *Local plans* have not been prepared in a commune, any changes in the land use can be made only by a so - called *decision on land development.*

The hierarchy of spatial planning in Poland is presented in the table 3.1 below.

Table 3.1 The hierarchy of spatial planning (MINIGO 2011), (Ministry of Environment & Ministry of Economy 2011)

Title of the document	Author	Content
Strategy for development of Poland	Central government	Strategic vision for development on national level
Concept of spatial development of Poland	Ministry of Regional Development + Central government	• Gathers all goals from the governmental *Strategy* and other documents. • Describes the rules of sustainable development based on natural, cultural, social, economic and foreign cooperation conditions, states the goals and directions of the sustainable development in Poland (housing, natural protection, infrastructure, water management etc.)
Strategy for development of the province	Local government (province)	Strategic vision for development on regional level
Plan for spatial development of the province	Local government (province)	• Incorporates the *Concept of spatial development*, *Strategy for development of province* and governmental programmes. • Considers the results of local studies and analyses. • Describes the basis of spatial planning and infrastructure in the area, natural protection sites, location of mineral deposits etc.
Study on conditions and directions of spatial development in the commune	Local government (commune)	• Incorporates the rules from the *Concept*, *Strategy for development and Plan for spatial development of the province* and any existing commune strategies. • Considers the current land use, the state of natural protection and conditions of living, energy

		supply etc. • Indicates structural changes needed and specific areas where new investments can be situated (e.g. energy infrastructure) • Is consulted with a commission of architects and town planners, province, neighbouring communes etc.
Local plan of spatial development	Local government (commune)	• Incorporates the *Study* and documents concerning security of the country • Indicates in detail how the specific areas should be used, states specific building parameters, division of parcels, rules of modernisation, development of technical infrastructure • Is consulted with a commission of architects and town planners, neighbouring communes, provinces etc. • In 2007, only 24% of areas in communes drafted their *Local plans*
Decision on land development	Local government (commune)	• Prepared for individual cases, if no *Local plan of spatial development* has been prepared

According to (Ministry of Regional Development 2011), as of May 2011 a draft of new *Concept for spatial and land management of Poland* was undergoing intergovernmental consultations although no detailed information on the content of the policy was known at the time of this thesis.

3.2 Employment

This subchapter will briefly characterize employment in Poland, namely the average salary in Poland and basic information regarding the employment in the energy sector. Moreover, the unemployment will be also discussed, specifically the unemployment rate and unemployment allowance.

3.2.1 Average salary

The average monthly gross salary in both public and private sectors in Poland in 2009 and 2010 in euro (EUR) is shown in the table 3.2 below.

The values are calculated with the following official average exchange rate in 2009, 1 euro (EUR) = 4.33 Polish *złoty* (PLN), and in 2010, 1 EUR = 3.99 PLN (NBP 2011).

Table 3.2 Average monthly gross salary in Poland in 2009 and 2010 (Central Statistical Office of Poland 2011b)

	2009	2010
EUR	717	808

It must be remembered that even though the growth of salary between 2009 and 2010 seems high, one of the additional reasons are that the exchange rate of euro to Polish *złoty* has significantly decreased in 2010, thus resulting in higher amount in euro than in 2009.

3.2.2 Unemployment

The table 3.3 below shows the unemployment level in Poland (measured as an average rate of unemployed to the active population) throughout last few years.

Table 3.3 Average yearly rate of unemployment in Poland (Central Statistical Office of Poland 2011a)

2004	2005	2006	2007	2008	2009	2010	2011 (as of end of February)
19.5 %	18.2 %	16.2 %	12.7 %	9.8 %	12.1 %	12.3 %	13.2 %

It can be observed that since Poland joined the EU in 2004, the unemployment level has been changing quite significantly. Very high in 2004 and 2005, it dropped significantly between 2006 and 2008 due to the economic growth. However, as the world economic downturn belatedly hit Poland, since 2009, the unemployment level started to rise again and reached 13.2% at the beginning of 2011.

Additionally, according to (Ministry of Labour and Social Policy 2010) , the unemployment in rural areas is usually higher than in cities, but it largely depends on the region. Another issue is also a so – called hidden unemployment, when people are not registered as unemployed and support themselves e.g. through benefits received by members of their families.

The unemployment benefit can be received by a person without job that has worked at least a year during an 18-month period before registering themselves as unemployed. In 2009, the benefit was equal to 166 EUR in first 3 months and then 130 EUR. Each year the benefit increases by the last year's inflation (Gazeta Prawna 2011).

3.3 State budget

The state budget of Poland will be shortly described, in order to generally assess its condition and claim possible importance of additional revenues.

3.3.1 Revenues and expenditures

The structure of state budget of Poland in the running prices in 2008 and 2009 is shown in the table 3.4 below (average exchange rate in 2008, 1 EUR = 3.7 PLN, while in 2009, 1 EUR = 4.33 PLN

Table 3.4 Polish state budget structure (Ministry of Finance 2011a)

[million EUR]	2008	2009
Revenues	68 526.29	63 321.82
Expenditures	75 106.35	68 828.75
Difference	-6 580.06	-5 506.92
[million PLN]	**2008**	**2009**
Revenues	253 547.26	274 183.50
Expenditures	277 893.48	298 028.48
Difference	-24 346.22	-23 844.98

Since the large change in the PLN/EUR exchange rate may be in this case misleading, the data is shown in both euro and *złoty*. It can be noticed that Poland has been slowly recovering from the economic crisis that caused high deficit, with both revenues and expenditures higher in 2009 than in 2008, but the deficit slightly lower in 2009 than in 2008.

3.3.2 Tax rates in Poland

The tax rates in Poland are 18% and 32%, with the yearly tax – free personal allowance of 773 EUR.

The table 3.5 below depicts the way the income tax is calculated:

Table 3.5 Tax calculation in 2010 (Ministry of Finance 2011b)

Income (EUR)	Tax rate
Up to 21 436	18%
Above 21 436	3 719 EUR+ 32% of the sum above 21 436 EUR

3.4 Summary

This section will summarise the most important issues of the chapter 3.

The chapter 3 describes geographical situation, political administration and spatial planning in Poland and examines the following socio-economic issues: employment, and state budget.

The spatial planning and land management in Poland are regulated mainly through the *Spatial planning act* that assigns certain obligations and tasks to the central government and local governments. The central authority designs a national strategy for the development in general, while the Ministry of Regional Development incorporates all governmental goals and describes rules of sustainable development. Each province then prepares a development vision on regional level that contains visions of regional and central government, results of local studies and sets conditions for spatial planning, infrastructure, natural protection sites etc. in the area.

Each commune incorporates documents higher in hierarchy, as well as indicates structural changes and new investments (e.g. energy infrastructure) needed in local area. Communes are also supposed to prepare detailed *Local plans*, which are mostly substituted by *decisions on land development,* issued on individual cases.

It can be noticed that the planning system is quite complex and hierarchical and some changes, proposed in chapter 8, may be needed.

Finally, several problems occurring in the areas such as employment and state budget in Poland were pointed out. The unemployment, after a decrease three years ago, is slowly growing again. The state budget deficit remains more or less similar, because both expenditures and revenues have been growing. This thesis aims at finding ways to tackle those issues, while to improving prospects of biomass in Poland, which will be analysed in the chapters to come.

4 Biomass in Poland

This chapter will aim at analysing selected aspects of the current situation in biomass sector in Poland, namely through a review of literature concerning available potentials, biomass prices and supply market in general and the current problems in the sector.

As it was mentioned in the introduction of the thesis, one of the issues to be analysed is the lack of significant development of energy crops and straw for energy use in Poland, although it is widely suggested that such potential exists. However, in order to be able to state what amount of biomass is currently used and what could be the future potential, a general review of existing literature has been conducted.

The role of the chapter 4 is to provide sufficient, multi - source information concerning biomass potential in Poland, as well as general information on prices and supply, in order to have grounds for the next step, which is a mathematical modelling of the system in 2020 utilising different levels of biomass fuel. Both steps contribute to alternative technological scenarios that form the technical approach noticeable in the figure 4.1 below. Therefore, this chapter is an important element enabling researching a possibility of achieving the technical and socio – economic goals of the overall analysis.

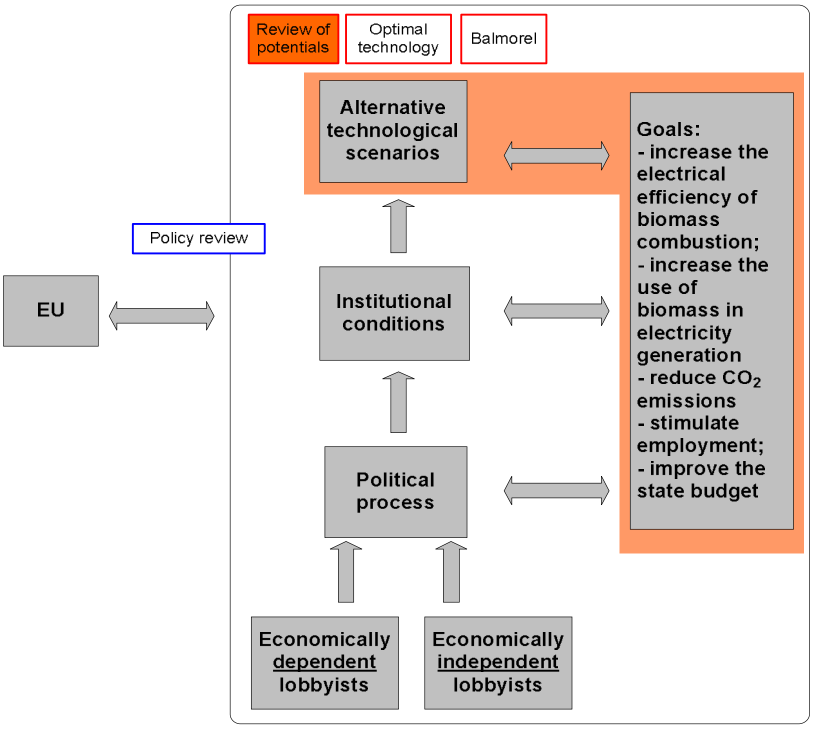


Figure 4.1 Theoretical approach to chapter 4

4.1 Review of potentials

This subchapter consists of three sections that will define categories of potentials, types of biomass taken into consideration, types of difficulties concerning assessment of biomass potentials and different assumptions made, as well as present the results of a literature review conducted regarding potentials of solid biomass in Poland. Various sources will be shortly discussed and finalised with a summary and assumptions presenting ranges of biomass potentials available to be achieved by 2020.

4.1.1 Types of potentials and influencing factors

According to (Gajewski 2011), (EEA 2006) and (Tanczuk and Ulbrich 2009) five categories of biomass resource potentials can be distinguished. These are the following:

Theoretical potential – the largest value, defined as the amount of energy achieved from biomass without deducting energy conversion losses and assuming complete land availability. This type of potential is hardly ever used as a basis for energy planning, because it is impractical.

Technical potential – theoretical potential decreased by losses from conversion of biomass fuel to the final energy carriers and spatial, technical and basic environmental restrictions. Although due to economic and market restrictions such potential can never be fully exploited in a year, it is useful, because it is relatively stable also in the longer time perspective.

Environmentally – compatible potential – defined in (EEA 2006) as the technical potential of biomass, considering no negative impact on soil, water and biodiversity and full compliance with all of the environmental policies now and in the future. It is assumed to be slightly more restrictive than the technical potential as described above.

Economic potential – the technical potential that has an economic value, it is dependent on fuel prices, taxes, economic indexes etc. It incorporates actual economy conditions and is very close to the market potential, described below.

Market potential – part of economic potential that can be used, assuming all the existing and planned policies and support schemes are implemented.

In this thesis, technical potentials were taken into consideration; however some caution was applied to the numbers found, preventing overestimation of the potential in view of certain economic and market boundaries.

An assessment of biomass potentials is a complex task, simply because it is a natural resource that needs to be developed and taken care of throughout the whole lifetime of a plant, thus many factors "on the way" may impede a goal that was set, for example certain yield or energy content. Additionally, concerns of biomass sustainability are incorporated to a varying degree in assessments, which also may be a cause of discrepancies.

(Scott Bentsen and Felby 2010) argue that any statistics on biomass resources have to be taken as incomplete and error – prone. This is mainly due to many interdependent factors, examples and explanations of which are shown in the table 4.1 below, based on (EEA 2006) (Scott Bentsen and Felby 2010) and own knowledge. Those factors influence different categories of potentials in different ways.

Table 4.1 Examples of factors influencing assessments of biomass resource potentials

Factor	Type of potential influenced	Impact on the estimation of biomass for energy purposes
Assumptions on yield (metabolism of a plant, biophysical factors, fertilizers, plant protection, mechanisation levels, water availability, occurrence of natural catastrophes such as drought, flood, pest).	Technical	Lower or higher potential than estimated.
Future developments, such as biotechnological improvements in energy crops or use of algae-derived biofuels.	Technical/economic	Higher potential than estimated through decreasing the usage of some plants for production of 2nd generation biofuels and releasing them for combustion. No changes, if more biogas will be produced from biomass of higher humidity.
Level of knowledge on agricultural techniques.	Technical	Lower or higher potential than estimated.
Increased future environmental restrictions (such as expansion of NATURA 2000 and national restrictions).	Technical/environmentally - compatible	Lower potential than estimated, unless those restrictions are accounted for in the estimations.
Transport and storage infrastructure	Technical/economic	Lower or higher potential than estimated.
Increased competition for wood used also in other sectors such as paper and furniture industry and competition for land with food production.	Economic/market	Lower potential than estimated.
Development of biomass market (possibility of exporting and importing biomass).	Economic/market	Higher potential than estimated, because not only local resources will be taken into consideration. Lower if it will make it more economical to export biomass.

4.1.2 Assumptions and limitations

In order to narrow down some of the uncertainties connected with biomass resource assessment that may influence the technological scenarios to be performed, a set of assumptions and limitations had to be made in relation to presented potentials.

The following are the assumptions and limitations of the resource estimation:

- It was not in the scope of this thesis to analyse the level of sustainability of biomass to be used, but rather it was assumed that in most of the literature reviewed, the sustainability criteria was taken into consideration to a certain extent.
- If no information was given on whether the represented potential is technical or economic, it was assumed that it represents a technical potential. However, in reality economic constraints exist that may hinder a possibility of fully exploiting the technically available potential.

- If no data is given regarding when the potential is expected to be realised, an assumption was made that it will be available to be achieved in 2020.
- In most of the cases, a potential in energy units was available and was later represented in PJ. Other energy units such as ktoe and GWh were converted to PJ, using factors from the International Energy Agency (IEA). In some cases, only information on mass was given, so assumptions concerning energy value of the fuel had to be made. However, the energy value of the biomass fuel changes due to the humidity, which may be influenced by the way of treating harvested biomass, but due to lack of information on water content, those differences could not always be incorporated into assessment. Based on (Bio Energia 2008b) the following assumptions were made:
  - For forest biomass, net calorific value of wood chips (17 GJ/t) was applied
  - For willow and miscanthus, 17 GJ/ t was applied, in case the so – called *dry mass* was used.
  - For straw, 9.7 GJ/t was applied
- As the notion of "biomass" includes many sources, the types of biomass taken into this assessment are: forest, energy crops (willow and miscanthus), wood waste and part of straw not used for other purposes.
- It was chosen only to analyse Polish market and resources, to avoid possible sustainability and additional cost issues in terms of long – distance biomass transport from abroad.
- All the natural conditions are assumed to be perfect, thus no drought, flood, pest influencing the yield was taken into consideration.
- The part of biomass, for example in the form of straw or wood pellets, used in the private household, is not in the scope of the thesis. However, it is known that biomass is used in individual households as of 2010 and probably will be in 2020, reducing the economic potential of biomass for professional energy generators, so this issue was implemented by not incorporating the full presented potential, but rather a range of numbers from different sources.

4.1.3 Forest biomass

This section will describe the current usage of biomass from forests and a discussion on possibility of increasing its share. The conflict regarding different industries using biomass will be also briefly mentioned.

As of the end of 2008, forests covered over 9 million hectares, corresponding to 29% of the landmass of Poland (The State Forests of Poland 2009b). It is visible from the figure 4.2 below that a great majority of forests in Poland is owned by the state, with only approximately 18% privatised.

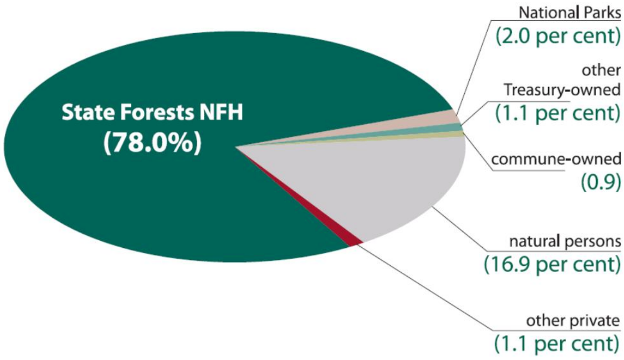


Figure 4.2 The ownership structure of forests in Poland (The State Forests of Poland 2009b)

According to (The State Forests of Poland 2009b), in 2008 the total timber resource for commercial purposes in the state – owned forests accounted for 1 676.2 million m^3. The amount of timber to be harvested in forest districts is set in 10 – year cutting plans, and sometimes due to natural catastrophes or plagues, it is increased.

The volume of merchantable timber harvested in 2008 in all forestry in Poland, including private forests National Parks, amounted to 32.4 million m^3, out of which 30.4 million m^3 was sold (The State Forests of Poland 2009b), (The State Forests of Poland 2009a).

The State Forests do not provide exact information on how much of the timber was destined to be used for energy use, but for the purpose of (NREAP 2010) an approximation regarding forestry usage and energy potential was made. In 2006, a total technical potential equalled to 6.1 million m^3 of wood which corresponds to 41.6 PJ of energy. For 2020, the NREAP estimates the technical potential of forest biomass for 87.13 PJ, so more than twice as high as now (NREAP 2010). It is understood that such increase will only happen, if more efficient and sustainable forest management techniques will be put in place.

According to (Gajewski 2011), 7.15 million t of forest biomass can be harvested yearly, which corresponds to 121.55 PJ. (Szlachta 2006) argues it can reach 101 PJ, while (EEA 2006) estimates it to be 1.5 Mtoe (62.8 PJ) and (IEO 2007) to 34.93 PJ. Forest residues and wood waste are estimated by (Rogulska, Pisarek and Wiśniewski 2002) to reach 113 PJ of potential, while wood waste: 237.04 PJ by (IEO 2007).

Currently, an important dispute occurs among different industries dependent on timber. It is viewed unfair by furniture and paper industry that the energy generators increasingly use forest biomass, being able to pay higher prices, instead of for example investing in developing energy crops. Since the possible solutions to this increasing conflict are not in the focus of the thesis, it is only mentioned generally in the chapter 8.

4.1.4 Energy crops

This section will describe the current usage of energy crops and the possibility of increasing the harvest areas.

There exist many species of plants available to be used as energy source in combustion installations. However, the literature reviewed focuses primarily on two most popular plants: willow (*Salix viminalis*) and miscanthus (*Miscanthus giganteus*).

According to (Vattenfall Polska 2011), a projected demand for biomass in 2020 will equal to 6.3 million tonnes of dry matter for power sector and 2 million tonnes of dry matter for heating sector, totalling for 8.3 million tonnes of dry matter. To reach these goals, assuming that the energy crops will contribute with the amount of 5.3 million t yearly, they should be grown on 0.5 million hectares in comparison with 10 000 hectares in 2010.

The figure 4.3 below shows areas of Poland, where the energy crops are allowed to be harvested (in grey), where the climate is too dry (in orange) and protected areas (in blue).

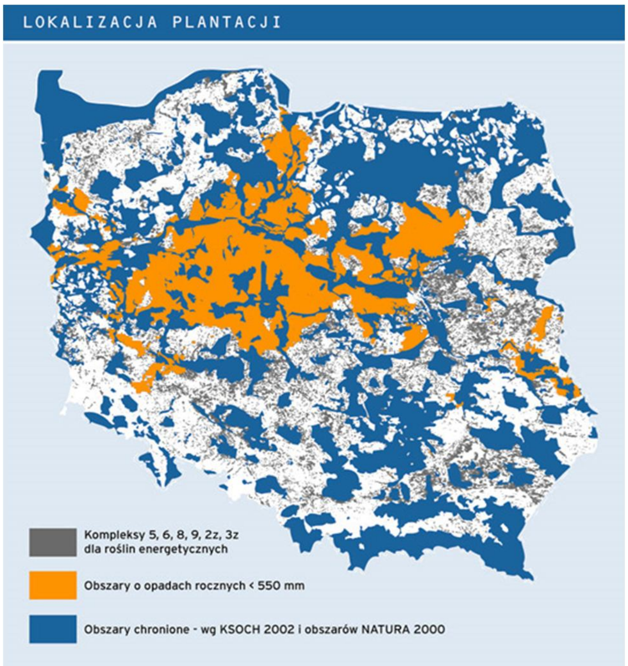


Figure 4.3 Possible localisation of energy plantations in Poland (in grey) (Vattenfall Polska 2011)

According to (Vattenfall Polska 2011), it is not recommended to harvest energy plants on good quality soils (about 54% of all arable land), areas protected and dry areas with the average sum of precipitation lower than 550 mm, because it may deteriorate the water management there and influence all other plants. It is visible from the figure 4.3 that the areas suitable for energy crops are spread more or less uniformly in whole country (except for central Poland), enabling steady future development.

According to (Szlachta 2006), if between 1.3 and 1.5 million of hectares of land were used for energy crops harvest, up to 400 PJ could be obtained each year.

Additionally, The European Environment Agency estimates that Poland has extensive potentials for biomass production (EEA 2006) and that the country has a possibility to increase it in the upcoming years. The overall potential for biomass in Poland is assessed by them for around 24 MtOE, with short rotation forestry and perennial grasses (e.g. miscanthus) estimated as able to provide around 9 MtOE (376.81 PJ), the rest contributing for biogas and ligno – cellulosic ethanol.

(IEO 2007) estimates energy crops potential to 479.17 PJ, while (Rogulska, Pisarek and Wiśniewski 2002) to 300 PJ.

4.1.5 Straw

This section will describe the current usage of straw and the possibility of increased use in the energy sector.

According to (Vattenfall Polska 2011), in the agriculture sector between 2004 and 2008 there were on average 9.1 million t of surplus straw, out of which at least 2.73 million can be used for energy purposes, accounting for 26.48 PJ.

According to (Gajewski 2011), the straw potential for energy purposes, calculated as the total amount of straw subtracting all the non-energy use, like fodder, is also significant. In 2010 the technical potential of straw was considered to be 5.65 million tones and in 2020 8.63 million tons (83.71 PJ).

(Rogulska, Pisarek and Wiśniewski 2002) estimate the potential for straw and hay to 130.00 PJ.

4.2 Summary of potentials

This chapter will present a sum - up of all the different technical potentials for solid biomass and ranges that will form a basis for assessment of how much biomass could be used in new technologies to be installed in "New biomass 2020" scenario".

A multi – source literature review has been made regarding selected solid biomass potentials and all the mentioned sources and values are summed up in the table 4.2 below. It is noticeable that the range of biomass potentials expected to be achievable in the future varies significantly. Moreover, some patterns can be observed, such as the fact that individual researchers tend to be more "optimistic" than companies. It may have to do with a difference in the way both groups treat a technical and economic potential, even if in all of the sources a technical potential was supposed to be estimated.

Table 4.2 Summary of literature review on future biomass potential in Poland

Type of biomass	Source	Potentials in 2020 (PJ)
Forest biomass	(NREAP 2010)	87.13
Forest biomass	(Gajewski 2011)	121.55
Forest biomass	(Szlachta 2006)	101.00
Forest biomass	(EEA 2006)	62.80
Forest biomass	(IEO 2007)	34.93
Forest residues and wood waste	(Rogulska, Pisarek and Wiśniewski 2002)	113.00
Solid wood waste	(IEO 2007)	237.04
Energy crops & forestry	(EEA 2006)	376.81
Energy crops (willow and miscanthus)	(Vattenfall Polska 2011)	90.10
Energy crops	(IEO 2007)	479.17
Energy crops	(Rogulska, Pisarek and Wiśniewski 2002)	300.00

Straw	(Vattenfall Polska 2011)	26.48
Straw	(Gajewski 2011)	83.71
Straw and hay	(Rogulska, Pisarek and Wiśniewski 2002)	130.00
All types of solid biomass for electricity generation	To be used in Poland in 2020 (NREAP 2010)	36.72

Taking into consideration the fact that only approximately 36.7 PJ are planned to be used in 2020 in Poland, according to (NREAP 2010), one may see that there is enough potential to increase the share of biomass in electricity generation even more. Since a decision had to be made regarding which potentials will be taken further into scenario modelling of the Polish energy system, "New biomass" scenario will utilise biomass providing approximately 17% of electricity generation (162 PJ), in order to allow doubling the share of RES in comparison to official goals.

4.3 Biomass market

This subchapter will very briefly discuss the supply and prices of biomass in Poland.

No data as of 2010 was available regarding the exact share of specific sources of biomass in the professional power and heat units in Poland. However, the statistics from (ERO 2011) show that the main fuels used at the moment are: wood and waste wood from forestry, to a lesser extent straw and energy crops in a small amount.

Currently, most of the biomass producers are individual farmers that sell biomass to pellet producers straight to the plants. In some cases, the energy generators lease fields from farmers and grow plants for their own purpose. So far, there has been no real biomass stock exchange or even a fully developed market.

However, according to (ETA Florence Renewable Energies 2009), Poland is becoming an emerging wood pellet market, meaning that although biomass production and consumption is still developing, stronger actors start appearing in the supply market between them. The estimated wood pellet production in 2009 was 340,200 t, out of which 120,000 t were consumed domestically (in power plants, heat boilers and individual heating) and 220,200 t were exported. Most of the pellet manufacturing companies are medium or small, with their own distribution system (ETA Florence Renewable Energies 2009).

It is expected that by May 2011, a biomass stock exchange will start operating. The main role of it will be to supplement the bilateral contracts that exist in the market as of now. It will act as an internet platform of trading chemical energy of biomass, followed by a physical trade and transport of biomass. Transactions of buying and selling biomass will be operated through auctions and only after concluding the transactions, the participants will know who they signed the contract with, however each commodity will be thoroughly described and presented. The participants can be producers of unprocessed biomass (sawdust), processed biomass (briquettes, pellets), sources for biogas generation, as well as intermediaries and energy generators (wnp.pl 2011), (Majewski 2011), (Blizniak 2011).

Regarding forest biomass, the rules of timber trade are set by the General directorate of the State Forests. It is sold in two 6-month-long cycles, where 50% of the offered timber is sold through limited tenders, and the remaining 50% on internet auctions (PGL - Lasy Panstwowe 2010).

Since there is no large market for biomass in Poland, but the trade is conducted rather through bilateral contracts, it is difficult to get the data on prices as they become simply a trade secret. Therefore, due to the incompleteness of publicly available information on Polish biomass prices, adjusted prices from Danish Energy Authority (Energistyrelsen 2009) were used and can be seen in the Appendix B.

4.4 The current problems of the sector

A number of issues exist in the biomass sector in Poland, thus hindering a possibility of understanding what the potential of biomass is and what the optimal usage of it is. The two most important problems identified are the following: supposedly inefficient use of biomass fuel in the power plants and CHPs as of 2010 and underdevelopment of biomass potential.

4.4.1 Biomass combustion

The main cause of the inefficiency is considered to be co - firing with coal in low efficiency. It is known from some of the plants' websites that generally biomass contributes with between 1% to 10% of the overall fuel in the different co – firing units, probably due to the fact that further investments would be needed (to protect the boilers from damage or to install better filters), should more biomass be combusted.

The electrical efficiency of the plants using biomass fuel is estimated to be on average of about 30%. This issue is discussed more in the chapter 6.2, where the units are modelled as part of the system in 2010. The legislation regarding green certificates is described in chapter 8.4.

4.4.2 Biomass potential underdevelopment

The problem is connected with not fully utilising the potential of biomass in Poland and the difficulties for energy crops famers to sustain their business. Currently, wood is used most often in the Polish energy sector and even has a potential to increase, but the lower quality soils not used for food production could be exploited to provide fuel from energy crops. This issue however has a number of barriers, discussed further in chapter 8.5.

4.5 Summary

This section will summarise the most important data in the chapter in connection with the problem formulation.

This chapter analysed selected aspects of the current situation in biomass sector in Poland, through subchapters concerning a review of literature on available potentials, biomass market in general and the current problems in the biomass sector.

In order not to risk too overstated or understated goals, it was decided to rely on more than one literature source and conduct a review of different data concerning biomass potentials in Poland.

Five categories of potentials were defined, of which the technical potential was analysed in the following subchapters. Moreover, some of the influencing factors concerning potential assessment were also mentioned. Additionally, assumptions and limitations made for the review were introduced.

The results of a literature review conducted regarding potentials of solid biomass in Poland show quite a significant potential available. However, various sources claim different data, which is caused by many factors, for example different methodology, assumptions on yield, extend of implementation of spatial and environmental restrictions.

All the data was summarised and assumptions presenting ranges of biomass potentials available to be achieved by 2020 were depicted. The numbers shown differ to a large extent, so it was decided to model the electricity system generating approximately 45.02 TWh of electricity from biomass (17% of electricity production), especially since the technical potential allows for it.

Additionally, a brief description of the Polish biomass market and prices was made, showing the most important features and trends.

The main fuels used are considered to be: wood and waste wood from forestry, straw and energy crops in a small amount. The production is done mainly by individual farmers who then sell their products to pellet producers or straight to the plants via bilateral contracts, while sometimes the energy generators grow plants for their own purpose on fields leased from farmers. The first Polish biomass stock exchange is expected to start operating in 2011. Half of the trade of forest timber is done through limited tenders, and the other half on internet auctions, managed by the Polish State Forests.

Moreover, the urgent problems in the biomass sector, corresponding with the aforementioned problem formulation, were identified, namely too low efficiency of biomass combustion CHP and power plants installations in Poland and the underdevelopment of biomass market.

5 Optimal technology choice

This chapter will provide general information on available biomass technologies and the data and assumptions needed to conduct an overview calculation of expected electricity costs. The chosen most cost - efficient technology will serve then as a basis for installing new biomass plants, replacing the old ones.

As it can be seen in the figure 5.1 below, the optimal technology choice is one of the elements contributing to the alternative technological scenario that in turn belongs to the technical theoretical approach. By reviewing a range of available technologies and making simplified electricity cost calculations, identification of the most favourable technology is done. This selection is later compared with the choice of investments conducted by the modelling tool in chapter 6.

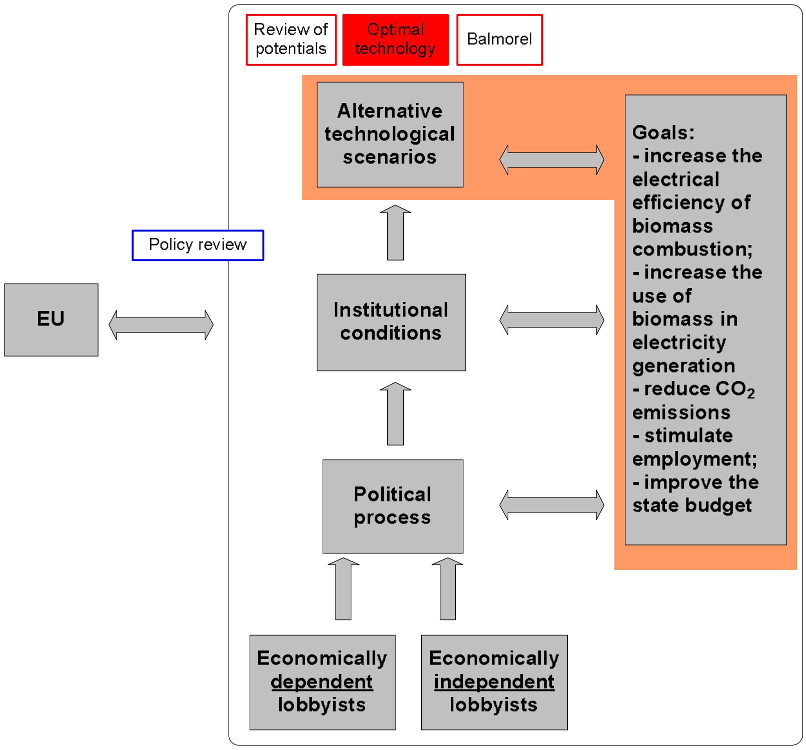


Figure 5.1 Theoretical approach to chapter 5

5.1 Range of technologies

This subchapter will shortly describe the electricity and heat technologies suitable for using solid biomass and provide information sufficient to choose most optimal from a point of view of expected electricity cost.

All the technology types used in the calculation are presented in the table 5.1 below:

Table 5.1 Short characteristics of plants used in expected electricity costs calculations (Danish Energy Authority 2010)

Plant type	Typical capacity (MW)	Brief characteristics	Efficiency (%)
Advanced Pulverized Fuel Power Plant fired by wood pellets (APFPP-wood)	240 – 400	Large units combusting fuel (e.g. wood pellets) that is pulverised before being ignited. The steam obtained is	47

		of supercritical type (above 250 Ba and 560°C).	
Medium CHP fired by straw	10 – 100	A unit is composed of: feed-in system, steam boiler and turbine, generator and heat recovery boiler.	29
Medium CHP fired by woodchips	10 – 100	A unit is composed of: feed-in system, steam boiler and turbine, generator and heat recovery boiler.	47
Small CHP fired by woodchips	0.6 – 4.3	A unit is composed of: feed-in system, steam boiler and turbine, generator and heat recovery boiler.	25
Small CHP fired by straw	8 – 10	A unit is composed of: feed-in system, steam boiler and turbine, generator and heat recovery boiler	30
Staged down-draft biomass gasification CHP fired by woodchips	1 – 20	The process is based on converting a solid biomass fuel through pyrolysis and gasification. Obtained gas is used in a gas engine to generate heat and electricity.	41
Updraft biomass gasification CHP fired by woodchips	1.4	The process is based on converting a solid biomass fuel through pyrolysis and gasification. Obtained gas is used in a gas engine to generate heat and electricity. Fuel and gas in this technology have opposite directions of flow.	26
Gasification biomass CHP with Stirling engine fired by wood	35 – 40	The process is based on converting a solid biomass fuel through pyrolysis and gasification. Obtained gas is ignited in combustion chambers and the resulting flue gases are used to heat the Stirling engine, which in turn drives an electricity generator.	22

5.2 Cost of electricity

This chapter will analyse the costs of solid biomass technologies and provide information sufficient to choose most optimal from a point of view of cost of electricity. This will serve then as a basis for building "new biomass" scenario for Poland in Chapter 6.

The calculations made can be defined as an approximate sum of all costs that appear during the lifetime of investment divided by the amount of energy produced during that lifetime, in currency/MWh. To reach the final electricity cost, the following equation was used:

Electricity cost = fuel cost + total O&M + annual investment - heat income

In order to be able to quickly decide which technology is the most cost-efficient, a set of calculations of generated electricity costs were made, presented in subchapter 5.2.2.

5.2.1 Assumptions

Below in the table 5.2 data sources, as well as other assumptions, are depicted.

Table 5.2 Data sources in calculations of electricity cost

Type of data	Value	Source
Power, heat and total efficiencies	According to specific technology (see table 5.3)	Danish Energy Authority
Investment and operation and maintenance costs	According to specific technology (see table 5.3)	Danish Energy Authority
Fuel prices (€/GJ)	Straw = 5.78	EA Energy Analyses-calculations for Danish Energy Authority
	Wood chips = 6.12	
	Wood pellets = 9.29	
Heat price (€$_{2009}$/GJ)	Heat generated from biomass = 7.00	Polish Energy Regulatory Office (ERO)

Other assumptions:

- 2020 costs are represented as in (Danish Energy Authority 2010). If a range of costs is given, a median is taken.
- In (Danish Energy Authority 2010) the total O&M costs for small woodchip and straw CHPs are a percentage of the annual investment (3.5% for woodchip CHP/4% for straw CHP).
- In (Danish Energy Authority 2010), the cost does not consider infrastructure and electricity transmission.
- Generally, in case of multi - fuel technology type, the cheapest fuel was applied, but for AFPP more expensive wood pellets are preferred.
- An annual value of the investment cost per MWh is calculated using the discount rate of 5 %. The O&M costs are not discounted (Danish Energy Authority 2010).
- The production itself is not discounted.
- The lifetime of each plant is assumed for 20 years.
- The number of the full load hours is assumed for 4000.

5.2.2 Results

The analysis will result in choosing a most cost - efficient electricity and heat producing biomass technology for Poland that will be implemented in the 2020 system, replacing the decommissioned technologies.

The calculations made and results obtained are presented in the table 5.3 below.

Table 5.3 Calculation of costs.

	APFPP	Medium straw CHP	Medium wood chips CHP	Small wood chips CHP	Small straw CHP	Staged wood gasification CHP	Updraft wood gasification CHP	Gasification CHP + Stirling engine
Fuel type	wood pellets	straw	wood chips	wood chips	straw	wood chips	wood chips	wood chips
Capacity (assumed)	1	1	1	1	1	1	1	1
Investment (€/MW)	1 400 000	2 200 000	1 600 000	3 950 000	3 900 000	2 600 000	3 600 000	3 600 000
Power efficiency	0.47	0.29	0.47	0.25	0.30	0.41	0.26	0.22
Heat efficiency	0.47	0.69	0.50	0.75	0.60	0.59	0.69	0.68
Fuel price (€/GJ)	9.29	5.78	6.12	6.12	5.78	6.12	6.12	6.12
Fuel price (€/MWh_fuel)	33.44	20.81	22.03	22.03	20.81	22.03	22.03	22.03
Fuel cost (€/MWh)	71.16	71.75	46.88	88.13	70.54	53.74	84.74	100.15
Variable O&M (€/MWh)		6.10	3.20	8.30		16.00	18.00	20.00
Full load hours (assumed)	4 000	4 000	4 000	4 000	4 000	4 000	4 000	4 000
Fixed O&M (€/MW/year)		38 000	26 000			54 000	180 000	30 000
Fixed O&M (€/MWh/year)		9.50	6.50	0.00	0.00	13.50	45.00	7.50
Total O&M (€/MWh/year)	7.00	15.60	9.70	2.77	3.13	29.50	63.00	27.50
Heat income (€/GJ heat)	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Heat income (€/MWh el)	25.20	59.96	26.81	75.60	51.25	36.26	66.88	77.89
Investment annually (€/MWh)	28.08	44.13	32.10	79.24	78.24	52.16	72.22	72.22
Electricity cost (€/MWh)	81.04	71.53	**61.87**	94.54	100.65	99.13	153.08	121.97

The table 5.3 above depicts results of the conducted calculations. It can be seen that although the commonly used technologies, such as wood chip – fired CHP, are cheaper, newer technologies such the biomass gasification, although still expensive, are becoming more and more competitive. Two technologies have the highest power efficiencies of 47% : AFPP plant and medium wood chip CHP, but it is the latter that is the least costly of all analysed, amounting for almost 62€/MWh.

The figure 5.2 below explains in a graphical way the reason behind such result. AFPP technology has a high fuel cost. This cost is lower in the wood chip - fired CHP, which is efficient, but also utilises cheaper wood chips. Even though this technology has relatively modest heat revenues, the investment cost are also quite low in comparison to other biomass technologies, allowing obtaining the overall most cost – efficient result.

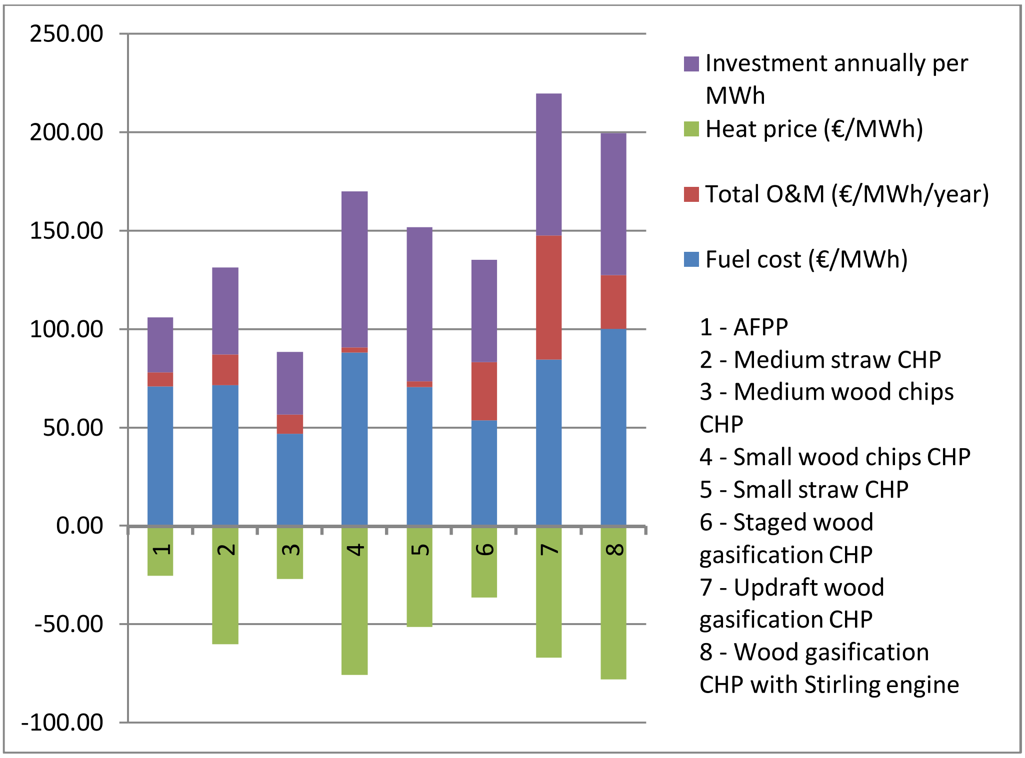


Figure 5.2 Important elements of the technology cost structure

Taking into consideration all of the aspects, it was decided that a woodchips-fired medium CHP is the most optimal technology to be used. As the timeline of the scenario is 2020, any not fully commercial technology is not expected to develop in Poland. However, in the more long-term horizon, more innovative technologies could also gain meaning, such as for example biomass gasification. This could strengthen the innovation level in Poland and further increase the benefits of implementing new biomass technologies, making Poland a leader and creating even more jobs for technicians and engineers.

5.3 Summary

This section will summarise the chapter 5.

This chapter provided general information on available biomass technologies and the data and assumptions needed to conduct an overview calculation of expected electricity costs.

Taking into consideration the criteria of energy cost and electrical efficiency, it was decided that a wood chips-fired medium CHP is the most optimal technology, because it has the highest efficiency and is the cheapest.

It has to be mentioned that, even if due to the relatively short – term perspective, the 2020 scenario will focus only on the aforementioned technology, in the more long-term horizon, other, more expensive, but innovative technologies could also be installed, making Poland a leader and creating even more jobs for technicians and engineers.

6 Power system scenarios

The power system scenarios will depict the current situation and three alternatives for the year 2020. The most important results will be shown, such as biomass share, efficiencies and CO_2 emissions.

As it is described in more detail in the chapter 4, the main problems of the biomass sector are low efficiency of biomass plants and underdevelopment of the biomass usage in the energy system. The focus of the thesis is to improve the efficiencies and increase the amount of biomass used in the Polish energy system in 2020, whilst manifesting changes in state budget and employment. Those important issues should be analysed as part of an energy system and different interdependencies that happen in it. The way that the theoretical approach applies here is explained more in the figure 6.1 below.

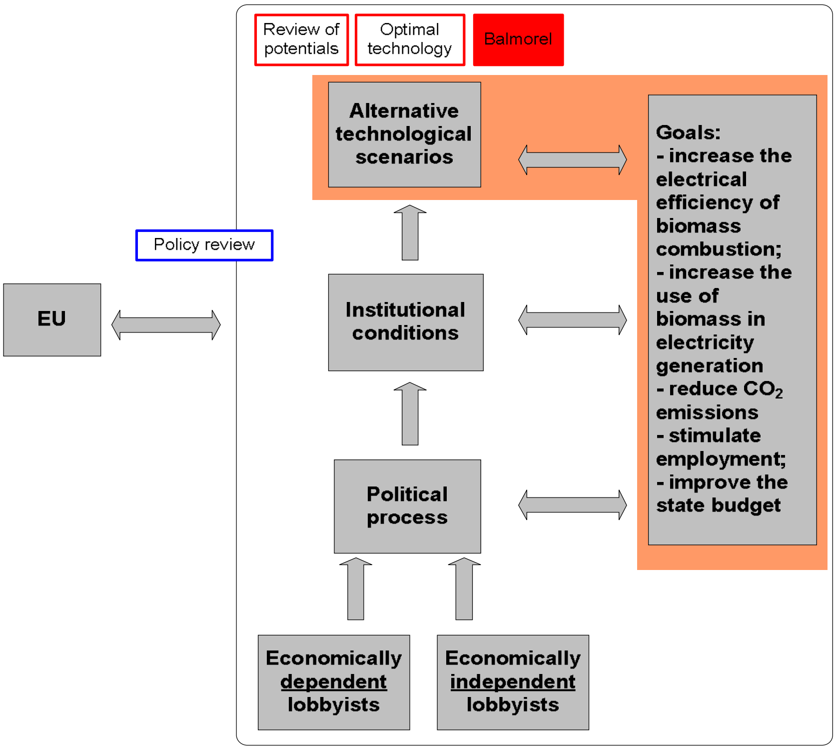


Figure 6.1 Theoretical approach to chapter 6

It situates the technical approach of the thesis in the form of alternative technological scenarios in the overall theoretical approach of the thesis. Thus, a number of scenarios are modelled that allow analysing the possibility of achieving technical goals, namely increasing the electrical efficiency of biomass combustion and increasing the use of biomass in the electricity system in 2020.

In total, four scenarios are modelled in Balmorel. First is a 2010 scenario showing the power system as represented in the Polish *National Renewable Action Plan* (NREAP 2010), with some modifications regarding biomass utilisation, based on (CIRE.pl 2011). Second is a reference 2020 scenario, based on (NREAP 2010) and (Ministry of Economy 2009). Third is an efficient 2020 scenario incorporating all new biomass capacities and scrapping the old ones. Fourth is another 2020 scenario with increased biomass utilisation in the system. The Balmorel modelling tool was used in all of the scenarios, with the following criteria for assessing the advantages and disadvantages of the proposed scenarios:

- Level of generation of electricity from biomass

- Plant efficiencies
- CO_2 emissions

Finally, each of 2020 scenarios is discussed taking into account all of the criteria mentioned above.

6.1 Balmorel modelling tool

6.1.1 General introduction to Balmorel

Balmorel is an open source modelling tool developed between 1999 and 2001 in cooperation with the Danish Energy Research Program. It serves technical analyses of electricity and CHP systems as well as energy and environmental analyses of market and policy issues, and can be flexible through add-ons. Examples of energy system issues that the tool can be used for are: market power, heat planning, development of transmission networks, etc. Each topic can then be analysed according to chosen methodology, for example: market or regulatory design, scenario analyses etc. (EA Energy Analyses n.d.)

According to (Connolly, et al. 2010) seven main types of all the energy modelling tools available on the market could be determined. Out of these, Balmorel has six features, as shown in the table 6.1 below:

Table 6.1 Balmorel features and characteristics with regards to the problem formulation (Connolly, et al. 2010) and own analysis

Type	Characteristics	Relevance to the problem formulation
Simulation tool	Simulates supply and demand in an energy system operation, in hourly time-steps and one year time-period	Allows to analyse how biomass resource is used or how could be used in energy system, through simulating as close as possible the existing or designed energy system
Scenario tool	Merges annual outputs into a long-term scenario	If long – term biomass scenarios were to be made, it could help design the steps required
(Partial)Equilibrium tool	Tries to explain supply, demand and prices as a part of or in whole economy.	Analyses if biomass is the most optimal fuel to be used given market circumstances
Bottom-up tool	Specifies and analyses certain technologies for investment identification	A range of technologies can be inserted in the model, while giving a model a possibility to choose some of them
Operation optimisation tool	Finds the best solution for the operation of the system	Analyses if biomass is the best fuel to be used given technical circumstances and where should biomass capacities be situated
Investment optimisation tool	Finds the best investment solution	Allows to find a most optimal investment in biomass for the country, taking into consideration certain constraints

The table 6.2 below shows the empirically observed strengths and weaknesses of the Balmorel modeling tool in terms of the analyses needed to respond to the research question.

Table 6.2 Strengths and weaknesses of the Balmorel tool

Strenghts	Weaknesses
Open-source and can be modified, so any technology type can be implemented, if enough data is known	In some cases more detailed data collection and calculations is required to fully use the core model (e.g. Cb and Cv value)
Partial equilibrium - type of tool, so it is well suited for market analysis	One must make sure to add different constraints on the model and policy goals, so that it considers RES goals or CO_2 emission caps
Geographical layering can be used for setting boundaries for electricity flow between different regions	
Good for modelling CHPs (allows to simulate two kinds of CHP)	
Results easily extracted to MS Access and from there to MS Excel/Word	

It is understood that in order to truly represent all the strengths and weaknesses of a modelling tool, one would have to compare at least two tools in the course of analysing the same research problem, but it was decided nonetheless that Balmorel will be suitable for the purpose of this thesis, because it is able to model combined electricity and heat (new CHPs), as well as allows to analyse performance of each unit.

6.1.2 Model of Poland in Balmorel

The main characteristic of the Polish model in Balmorel need to be described, so that the assumptions made in the modelling sections are better understood.

6.1.2.1 Geographical division

Poland in the model is divided into five regions. The division was made based on available data concerning different levels of grid development, various patterns in electricity consumption and corresponding data on administrative level and different wind power potentials as well as capacities installed. The figure 6.2 below displays the final five regions. Additionally, it can be seen that each Balmorel region consists of three to four administrative regions (the figure does not represent the Balmorel areas division).

Figure 6.2 Polish regions in Balmorel

The division was also inspired by different graphical representations of the grid found, as shown in the figure 6.3 and 6.4.

Figure 6.3 Scheme of the EHV and HV power grid. The administrative representation of the TSO consists of: PSE-Północ SA, PSE-Centrum SA, PSE-Zachód SA and PSE-Poludnie SA (PSE - Operator SA 2010), changed

It is noticeable that the grid is well-developed mainly in the South and Central Poland, with large hubs in bigger cities. At the time of the modelling preparation, the map was not represented with different administrative division off the PSE – Operator branches.

Another reason was a planning division presented in the Transmission System Operator's (TSO) *Development Plan*, see figure 6.4.

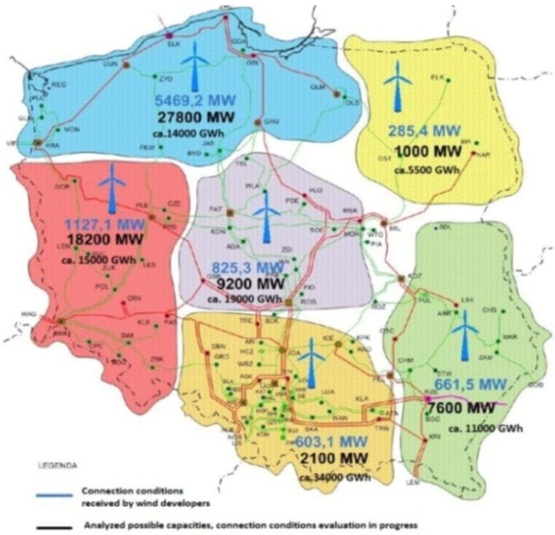


Figure 6.4 Analysed grid connection conditions for wind projects in 2009 and approximate electricity consumption in selected regions in 2007 (PSE - Operator SA 2010b)

Finally, a report by the American Argonne National Laboratory, using GTMax software, was also taken into consideration. GTMax (Generation and Transmission Maximization Model) is an energy, environmental and economic modelling tool that was used in analysing the market for small-scale gas CHP deployment in Poland. In that project the country is split into: Northern, Central, Eastern, Western and Southern Node (Argonne National Laboratory n.d.).

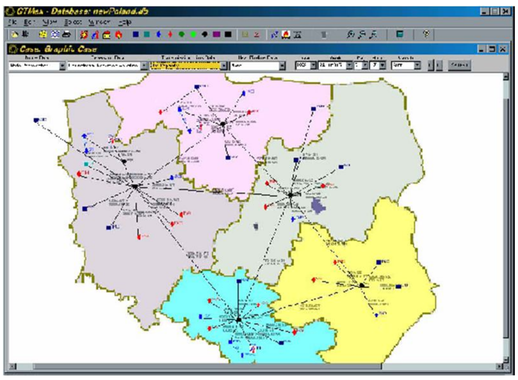


Figure 6.5 Division of Poland in GTMax modelling tool (Argonne National Laboratory n.d.).

However, due to the fact that no official information regarding permanent transmission bottlenecks (either technical or connected with the market) was found, it was decided to apply infinite transmission capacity among all the Polish regions.

Next, a division into areas comprised in regions was assumed. The data was provided from a data base published by (Polish Central Statistical Office 2010). Based on the information found, “Sales of district heating energy in 2008”, divided on the region and commune level, areas were created. The data for industrial areas was assumed as in the already existing model from 2004 and adjusted for 2007 with (Euroheat & Power 2009). Hydro, onshore and biogas areas are also represented in each of the regions. The reason for that was because the accurate information on geographical localization of some of those renewables was unknown, so in some cases the data for whole Poland was divided into five or adjusted in accordance with the current installed capacity. Onshore wind capacities in 2010 are displayed as one for each region. As for the division into areas, the table below shows how they are set in each Polish region. In most of the cases, an area is composed of all district heating consumers in a city and surrounding areas. Additionally, heat boilers to cover heat demands are added, calibrated with (Euroheat & Power 2009).

The table 6.3 below represents the area nomenclature in the model of Poland. The letters PL signify Poland, next four letters-the administrative region, final letters-name of the city with district heat or all region in case of "all", thus "PL_POMO_Gdan", means: **P**o**l**and-**Pomo**rskie-**Gdan**sk.

Table 6.3 Balmorel Polish areas

Balmorel region name	Condensing and CHP areas names	Areas with renewables	Industrial areas
PL_NW	PL_POMO_Gdan, PL_POMO_Slup, PL_ZACH_Szcz, PL_ZACH_Kosz, PL_KUJA_Bydg, PL_KUJA_Grud	PL_NW_Onshore, PL_NW_Offshore, PL_NW_HYR, PL_NW_BG	Auto1_U
PL_W	PL_LUBU_Gorz, PL_LUBU_Ziel, PL_WIEL_Pozn, PL_WIEL_Koni, PL_WIEL_Kali, PL_WIEL_Lesz, PL_DOLN_Wroc, PL_DOLN_Legn, PL_DOLN_Jele, PL_DOLN_Walb	PL_W_Onshore, PL_W_HYR, P L_W_BG	Auto2_U
PL_Central	PL_WARM_all, PL_PODL_all PL_MAZO_Wars, PL_MAZO_Ostr, PL_MAZO_Rado, PL_MAZO_Ciec, PL_LODZ_Lodz, PL_LODZ_Sier, PL_LODZ_Piot, PL_LODZ_Skie, ,	PL_Central_Onshore, PL_Central_HYR, PL_Central_BG	Auto3_U
PL_SE	PL_LUBE_Lubl, PL_LUBE_Pula, PL_SWIE_Kiel, PL_SWIE_Sand, PL_PODK_Rzes, PL_PODK_Prze,	PL_SE_Onshore, PL_SE_HYR, PL_SE_BG	Auto4_U
PL_S	PL_OPOL_Opol, PL_OPOL_Nysa, PL_SLAS_Kato, PL_SLAS_Rybn,	PL_S_Onshore, PL_S_HYR, PL_S_BG	Auto5_U

	PL_SLAS_Biel, PL_SLAS_Tych, PL_SLAS_ Byto, PL_SLAS_Gliw, PL_ SLAS_Sosn, PL_MALO_Krak, PL_MALO_Oswi, PL_MALO_NwyS		

6.1.2.2 Polish energy technologies

Except for newly constructed Balmorel model of Poland, created for the purpose of an earlier project, an older model of Poland existed and was used in previous analyses of the Baltic Sea region. However, the data represented was considered out-of-date as of 2010 and too aggregated, so a new model was built, representing professional plants, with the old data applied for industrial plants.

The current model represents each single unit of all professional thermal power plants and renewable sources in Poland as of 2009, amounting for over 300 units in total. A summary of data regarding fuels and technology types of power generation units in Polish model is represented in the table 6.4 below.

Table 6.4 Summary of Polish power units as of 2010

Type of fuel	Installed capacity (MW)
Biogas	80
Coal	21711
Fuel oil	224
Lignite	6335
Waste	34
Natural gas	737
Straw	491
Solar	1
Hydro	953
Wind	1100
Wood chips	460
Wood waste	144
Total	**32270**

As the thesis focuses on biomass, more exact data was needed to avoid underestimation of the current utilisation levels. In (NREAP 2010), only the 100% biomass - fired units are displayed, but the total electricity generation from biomass is included (100% biomass units and co – firing of coal with biomass). Moreover, there is no official data on how much exactly each unit uses in the co – firing scheme, so it had to be assumed based on data from plant websites and (Energy Market Agency 2010) and compared with the total amount of biomass used for electricity generation in 2010.

6.2 Scenario “2010 Power System”

This chapter will present the 2010 scenario.

It is necessary to model a scenario of the existing system to check the consistency of data in the model with the historical data. This scenario is modelled in order to show general features of the electricity and heat system in 2010 and generally compare them with statistical results, in order to have basis for arguing the correctness of 2020 BAU scenario.

6.2.1 Assumptions

All the assumptions regarding the modelling will be described, such as fuel prices, interconnections etc.

The following assumptions were made for modelling year 2010:

- It was decided to model Poland in the island mode, because at the time of the thesis submission, the complete scenario set – up from the other Baltic Sea region countries was not ready. Of course, such representation may then be a limitation to the results obtained and it does not fully represent the modelling possibilities of Balmorel tool.
- Due to a different nomenclature in Poland, having analysed the features of different units in (ARE 2010), the division into extraction and backpressure units was decided, based on features of specific units.
- Fuel distribution: co – firing units were split into two separate units that run on biomass and coal.
- Since Balmorel models both district heat and electricity, data was found on both complements of the energy system. However, the thesis focuses on electricity sector; therefore the results are presented only for this part. Assumptions on electricity demand are from the (NREAP 2010). Assumptions on heat demand were based on data found in (Ministry of Economy 2009), (Central Statistical Office 2010) and (Euroheat & Power 2009).
- Assumptions on C_v values for extraction and condensing units: the units before 1975 were given a C_v value of 0.2, older than from 1990: 0.18, the newest units have a C_v equal to 0.16. In a few cases the value had to be adjusted to avoid errors.
- Fuel prices: The exact prices used can be found in the Appendix B. For 2010, prices for fuel oil and light oil are taken from International Energy Agency’s (IEA) “World Energy Outlook 450 ppm scenario” (OECD/IEA 2010). This is a scenario for the future when a goal of stabilizing CO_2 level in the atmosphere at 450 parts per million (ppm) CO_2 eq is implemented. Thus, the prices of fossil fuels in this scenario increase until 2020, after when they remain stable for crude oil, decrease for coal and increase for natural gas as the least polluting fossil fuel. Prices for coal and lignite are adjusted as found on the Polish Energy Regulatory Office website (ERO 2011). Prices for straw, wood, wood waste, wood pellets and straw pellets are according to the Danish Energy Authority report (Energistyrelsen 2009), whose projections were based on historical and existing trends in biomass prices. As in the Polish system, “regular”, not upgraded biogas is used, for this fuel an assumption is made that it is slightly more expensive than natural gas in 2010 and cheaper in 2020.
- Industrial plants are assumed to be the same as in the old model, but biomass units are co – coordinated with (ERO 2011).
- Biogas and hydro capacities for Poland are equally divided into five regions.

- Fixed O&M assumptions (in k€/MW) were made based on the age and costs from the old model. Average costs of existing biomass technologies can be found in chapter 7.1.
- Variable O&M assumptions (in €/MWh) were made based on the size and costs from the previous model. Average costs of existing biomass technologies can be found in chapter 7.1.
- Full load hours are calculated by dividing the generation and capacity of renewable energy units, as presented in (NREAP 2010).
- The sum of capacities for renewables is similar to those in Polish (NREAP 2010), while the model is allowed to invest in other areas in renewable sources, but not necessarily in the strict way it is done in the Action Plans.
- A difference between biomass plants in Poland is observed. The official numbers concern only 100% biomass – fired plants and not co – firing. However, the electricity generation out of biomass was known, thus it served as a basis for assumption on how much biomass is used in Poland in 2010. As the thesis focuses on biomass and potentials, it was deemed necessary to incorporate that knowledge to the model. Thus, some of the plants are 100% biomass – fired, while the other plants are just co – firing part of the regular coal plants.
- Regarding this scenario, the data on Polish plants is based on 2009 figures, adjusted with (NREAP 2010). However, one have to remember that the Polish Action Plan was submitted in November 2010, so although it incorporates some statistical data already from that year, it does not mirror the system 100% as it was in 2010. Taking into consideration the fact that the Polish energy statistics body, ARE, usually issues its detailed statistical dataset on the energy system in October of the following year, a complete check – up for 2010 could not be done at the time of the thesis, although the dataset was checked for consistency with 2009 data, as was presented in a previous report made as part of the internship in EA Energy Analyses between September 2010 and January 2011.
- The notion of wood chips is related mainly to willow and to a lesser extent forest biomass (their energy value is similar).
- The following values of CO_2 emissions are attributed to the fuels used.

Table 6.5 CO_2 emissions for each fuel type (Energistyrelsen 2009)

Fuel type	CO_2 emissions (kg/GJ)
Natural gas	56.8
Coal	95
Lignite	101
Fuel oil	78
Municipal waste	32.5

6.2.2 Modelling results and analysis

The modelling results and the analysis for 2010 will be provided, including electricity generation, biomass use and biomass plant efficiencies as well as CO_2 emissions.

As can be seen in the table 6.6 the electricity generation in Poland in 2010 amounted for 150.31 TWh, out of which biomass represented 5.66 TWh.

Table 6.6 Electricity generation divided by source in 2010 Polish system

Fuel type	Production in TWh
Coal	85.23
Fuel oil	0.01
Lignite	50.14
Municipal waste	0.20
Natural gas	3.58
Solar PV	0.00
Hydro	2.46
Wind	2.57
Biogas	0.46
Biomass	5.66
TOTAL	**150.31**

The figure 6.6 below depicts a comparison of percentage shares of different fuels in the created 2010 system and the one provided in (NREAP 2010).

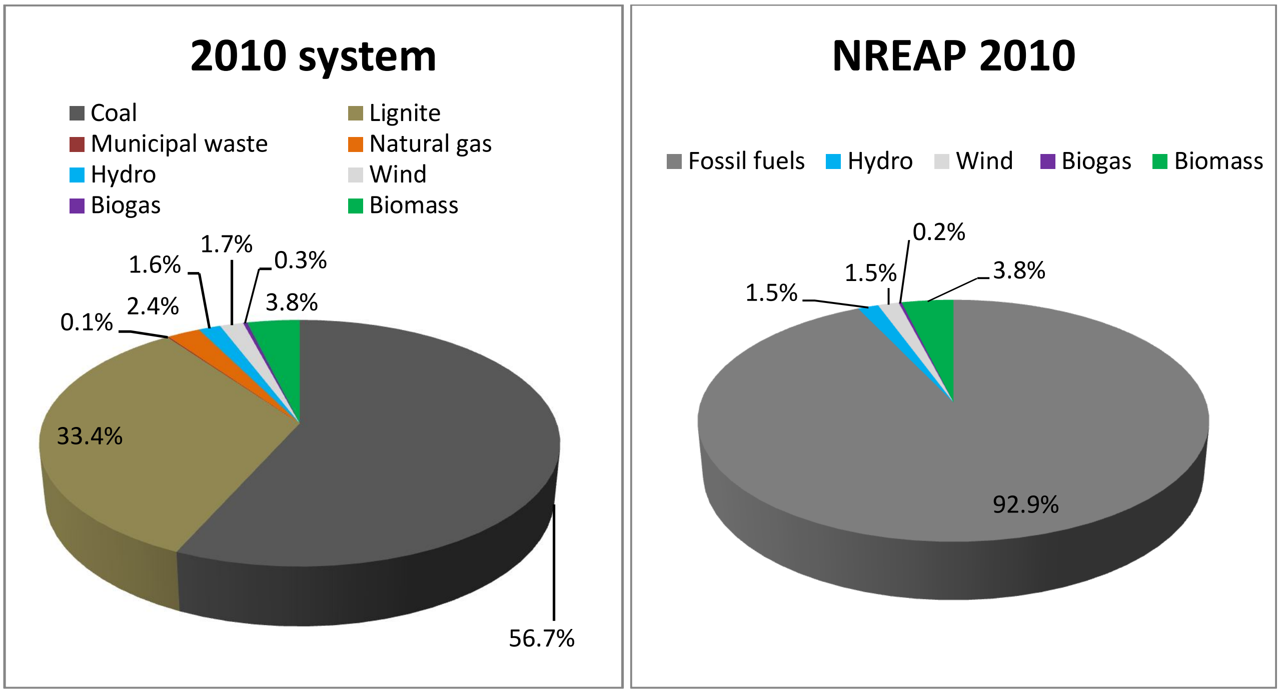


Figure 6.6 Comparison of the created 2010 system (on the left) and NREAP 2010 data (on the right)

It is noticeable that the biomass share in both cases is identical, comprising of approximately 3.8 % of generation, which allows saying that the model represents correctly this part of the system as of 2010. Thus, biomass is the largest RES in electricity production in Poland.

For comparison, a table below depicts the statistical data on use of biomass in the electricity production in 2010, which shows the obtained results are relatively similar to reality.

Table 6.7 Historic data on electricity generation from biomass in 2010 in Poland (CIRE.pl 2011)

	TWh
Total electricity generation	157.4
Co – firing	4.99
Other	0.86
TOTAL biomass	5.85

Some discrepancies appear in wind and hydro production, which are slightly higher than in the Action Plan. This can be explained by the fact that in Balmorel, only one type of wind technology is installed, while in reality and in the Action Plan (assumptions and goals of which were modelled with another tool), the technologies types could have been different – for example, some older generation wind turbines operate in Poland. Still, basic assumptions on inserting the same number of full loads hours and capacities as in the Action Plan resulted in a very similar result.

Another discrepancy is a slightly higher biogas production and in this case it may be caused again by technology differences or by a higher calorific value of biogas assumed in Balmorel than in the model used in Poland, however such details are not provided in the Action Plan, so this information could not be checked beforehand.

Regarding other fuels, they seem to total to the similar amount as "fossil fuel" category assumed to represent non – renewable fuels in (NREAP 2010). It can be seen that coal and lignite have been and are used extensively in Poland, altogether contributing for about 90% of the fuels in electricity production as of 2010.

The table 6.8 below shows electrical efficiencies of the biomass plants in the scenario, as well as the average electricity efficiency of all of them. It can be noticed that, though some of the plants have quite high efficiency, there are some of a very low efficiency that cause a low overall average.

Table 6.8 Electrical efficiencies of the biomass plants in the "2010 energy system" scenario

Name of the unit	Type of fuel	Electrical efficiency
BelcU4COF-CON-WW-1984_r2009	Wood waste	0.39
BialU1-BP-WO-1978	Wood chips	0.30
Chor2U1COF-BP-WW-2003	Wood waste	0.35
CHP_AUTO5-STR	Straw	0.40
Gdan2U4COF-BP-WO-1994	Wood chips	0.31
Jawo3U1COF-EXT-WO-1977	Wood chips	0.40
Kiel –BP-WO-2008	Wood chips	0.30
KoziU7COF-CON-WO-1974	Wood chips	0.39
KoziU8COF-CON-WO-1975	Wood chips	0.39
KrLegU1-EXT-ST-1985	Straw	0.33
Lodz4U3-EXT-WO-1992	Wood chips	0.29
OGrudU1COF-BP-ST-2009	Straw	0.11
OpolU4COF-CON-WW-1997	Wood waste	0.41
OstraU1-CON-WW-1958	Wood waste	0.15

OstraU2-EXT-WW-1958	Wood waste	0.15
OstraU3-BP-WO-1961	Wood chips	0.15
OstraU4-BP-WO-1967	Wood chips	0.15
OstrbU1COF-CON-WO-1972	Wood chips	0.40
OstroU2-BP-WO-2008	Wood chips	0.40
PolaU8-CON-ST-1983	Straw	0.40
SzczU1COF-BP-WO-2000	Wood chips	0.24
WrocU1COF-EXT-WW-1972	Wood waste	0.30
WrotU1COF-BP-WO-2002	Wood chips	0.30
ZeraU7COF-EXT-WW-2005	Wood waste	0.24
AVERAGE		**0.30**

The figure 6.7 below depicts total CO_2 emissions (from both electricity and district heat generation). In this scenario, they amounted to 147.68 Mt, with the highest contribution from coal and lignite. When compared with the International Energy Agency, in 2008 Poland emitted 298.69 Mt of CO_2 from fuel combustion (IEA 2011).The difference can be interpreted by the fact that in Balmorel only district heating sector is represented, therefore CO_2 emissions from individual heating are left out.

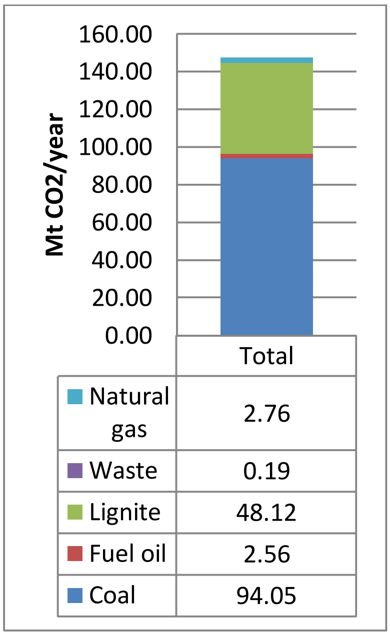


Figure 6.7 CO_2 emissions in "2010 Power System" scenario

6.2.3 Sum – up and conclusions

The aim of this analysis was to show results of constructing a scenario of the system as in 2010, which can serve as a basis for modelling of 2020 and compare it with the Action Plan data. In terms of electricity production, the created model seems to be working, there are some differences, but it is decided to be used as a basis for 2020 analyses. This also means that most of the assumptions turned out to be correct.

It is concluded that the discrepancies that occurred, might have been caused by lack of larger representation of RES technologies in the model, more suited to represent the technologies in reality, as well as possibly different values assumed for biogas calorific value in the model.

6.3 Scenario "Business as usual 2020 (BAU 2020)"

This chapter will present the first of 2020 scenarios, reference for the assessment of remaining two scenarios.

This scenario shows the consequences of using in 2020 the same biomass plants as in 2010 and additionally installing new plants to comply with the goals stated in (NREAP 2010) and (Ministry of Economy 2009).

6.3.1 Scenario assumptions:

- The electricity demand for Poland comes from the projections stated in (NREAP 2010), the district heating demand is from (Ministry of Economy 2009).
- All RES capacities are as if they were to be installed in 2020. This is an assumption other than in the NREAP assumptions that every year an investment is made, but this is done to focus on aggregated results.
- No exact data is known as of Polish nuclear plant presence, as well as the exact capacity is still to be decided by the government, however most probably it will be in full operation between 2021 – 2022. Thus it was decided not to include nuclear in the analysis, but coal investments have proven to be necessary in order to be able to cover the increasing demand between 2010 and 2020.
- Old plants will be used to generate biomass – based electricity plus new capacities will be installed to represent the goal of 17% of RES in electricity generation.
- Additionally, no co – firing goal was set in the model, so the green certificate scheme progression until 2020 could not be represented fully in the model.
- Due to the fact there are discrepancies between (NREAP 2010) and (CIRE.pl 2011) in term of how much biomass is actually used, 17% goal of electricity from RES sources is set (approximately the RES share as in the Action Plan and (Ministry of Economy 2009)
- Data on small wind installations presented in (NREAP 2010) is recalculated to represent ½ of regular onshore wind power units.
- Certain plants will be decommissioned, according to the data from (ENTSO-E 2011). The phase – out is based on producers' declarations and caused by environmental and technical requirements. Thus, it is assumed that between 2009 and 2025 the total amount of 9517 MW will be decommissioned, affecting the system.
- The table 6.9 shows the types and amounts of installed technologies.

Table 6.9 Technologies installed in the "BAU 2020" scenario

Technology	Total installed capacity (MW)
Hydro run – off – river	1152
Solar photovoltaic	3
Wind onshore	5875
Wind offshore	500
Biogas	980
Solid biomass old capacities	719
Solid biomass new	854

capacities	
TOTAL biomass	1573

The "old capacities" are the ones already existing in the system as of 2020, the new ones had to be installed in order to reach renewable electricity goals.

6.3.2 Modelling results and analysis

The modelling results and the analysis for "2020 Business as usual "scenario will be provided.

As can be seen in the table 6.10 the electricity generation in Poland in this 2020 scenario amounted for 202.83 TWh, out of which biomass represented 10.54 TWh.

Table 6.10 Electricity generation in "2020 BAU" scenario

Type of fuel	Production (TWh)
Coal	129.92
Lignite	35.63
Municipal waste	0.22
Natural gas	2.72
Solar	0.00
Hydro	2.97
Wind	15.48
Biomass	10.54
Biogas	5.34
TOTAL	**202.83**

It is visible that the electricity generation in comparison to 2010 is forecast to rise by 25% in 2020. According to this scenario, hard coal will still play an important role, while RES contribution will also grow, with wind becoming the largest source and biomass the second largest.

Below, in the figure 6.8, three diagrams are set together: for 2010 system, 2020 BAU (current scenario) and the data extracted from (NREAP 2010) as a representation of 2020.

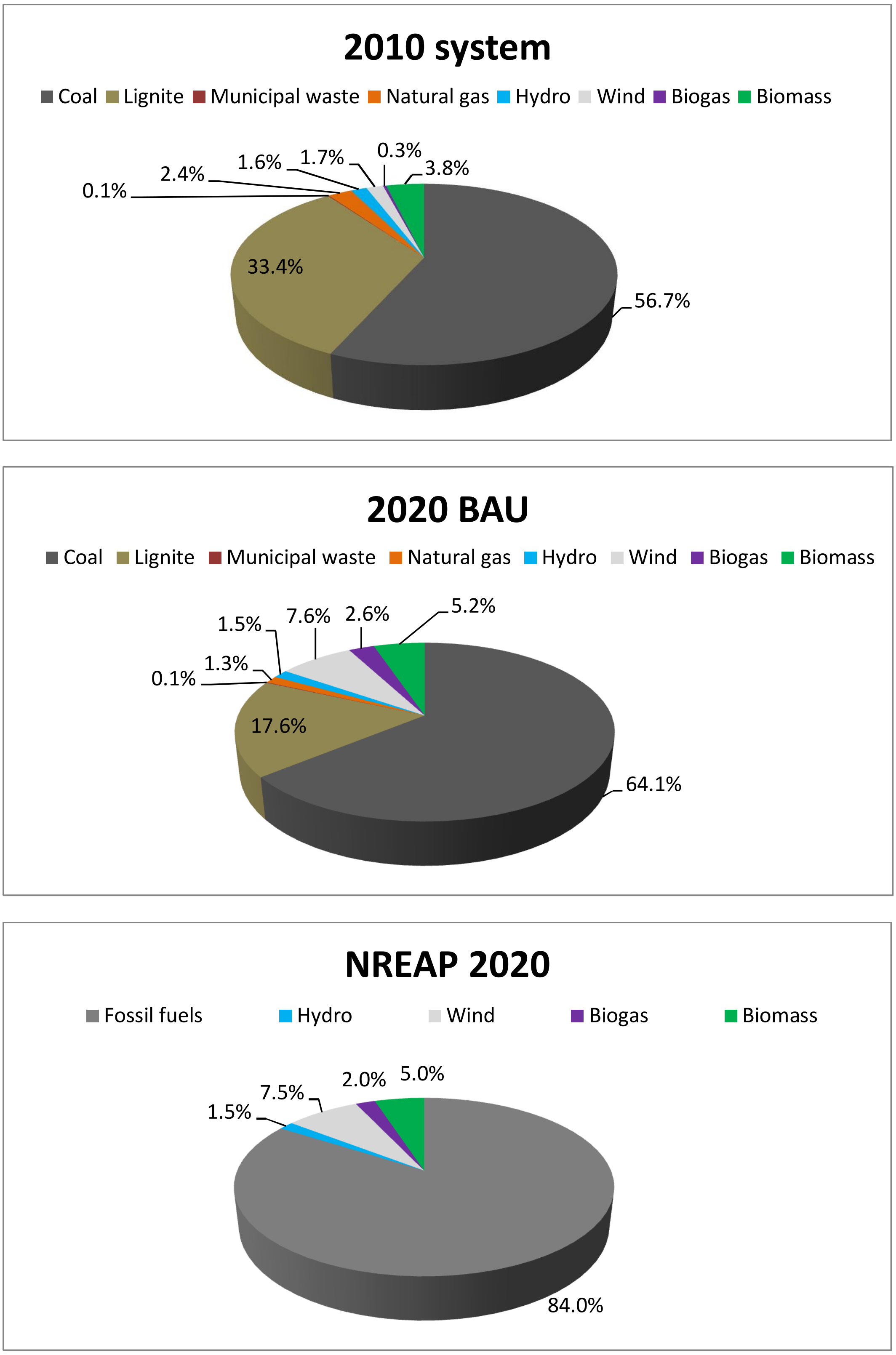


Figure 6.8 Comparison of the "2020 BAU" (in the middle) with the situation as in 2010 and as in the Action Plan for 2020.

When “BAU 2020” is compared with 2010 system, although the RES contribution grows, the coal – based production increases too. This is certainly caused by an increase in energy demand between those years and is likely to happen if the hard coal lobby in Poland will continue having its political strength. Although lignite plants production decreases almost twice, this situation can be justified by the fact that some of the lignite units will be decommissioned due to age and environmental restrictions, as well as no new plants on this fuel are planned to be built in the future. Interestingly, the natural gas shares are lower in 2020, which in view of the prices of this fuel, lack of sufficient Polish conventional gas resources and the fear of increased dependency on the practically sole supplier, Russia, is probably a correct assumption. Another issue are the recently found shale gas deposits in Poland that may cause higher production of electricity from natural gas; however this was not in the focus of this thesis.

A comparison of both scenarios in terms of RES shares, demonstrates that by 2020, the electricity generated from renewables more than doubles from 7.4% now to approximately 17% in 2020. The production from biomass increases by approximately 36%, while wind and biogas will have higher growth rates. Though the hydro production slightly increases, its share in the overall production is to fall by 0.1%, according to “BAU 2020” scenario.

Finally, a comparison of the modelled “BAU 2020” scenario with NREAP 2020 data is made. While the fossil fuel share is lower by approximately 1% in the current scenario, the RES share is also higher by the similar percentage. The hydro share is identical, but biomass, wind and biogas production is larger in this scenario than in the Action Plan. One of the reasons of 0.2% higher biomass share may be the way of conducting the modelling: the model was made to invest only in biomass extraction plants, choosing between two types, as well as fitting them in the right heat areas, where demand exists. However, regarding coal, since the model could not use more capacities than were installed exogenously (externally, not as a model calculation) in a few areas, it resulted in investing in the increased amount of biomass plants in the areas where demand existed, but no new coal capacities were installed. The discrepancies in terms of biogas and wind can be again justified by some technology differences. Another reason could also be the fact that units in (NREAP 2010) are installed year by year, so it is possibly assumed that some of those installed earlier will be already working with lower efficiencies in 2020, while the Balmorel technologies are as assumed to be in 2020.

When it comes to the changes in biomass plant efficiencies in “BAU 2020” scenario, the table 6.11 depicts them below:

Table 6.11 Electrical efficiencies of biomass plants in “BAU 2020” scenario

Name of the unit	Electrical efficiency
BelcU4COF-CON-WW-1984_r2009	0.39
BialU1-BP-WO-1978	0.30
Chor2U1COF-BP-WW-2003	0.35
CHP_AUTO5-STR	0.40
Gdan2U4COF-BP-WO-1994	0.31
Jawo3U1COF-EXT-WO-1977	0.40
KoziU7COF-CON-WO-1974	0.39
KoziU8COF-CON-WO-1975	0.39

KrLegU1-EXT-ST-1985	0.33
Lodz4U3-EXT-WO-1992	0.29
OGrudU1COF-BP-ST-2009	0.11
OpolU4COF-CON-WW-1997	0.41
OstroU2-BP-WO-2008	0.40
PolaU8-CON-ST-1983	0.40
SteamTur-EXT-WO-20_29	0.47
SzczU1COF-BP-WO-2000	0.24
WrotU1COF-BP-WO-2002	0.30
ZeraU7COF-EXT-WW-2005	0.24
AVERAGE	**0.33**

It is visible that the overall average electrical efficiency increased by 3% in comparison to 2010, because new biomass extraction units on wood chips, fitted with steam turbines, (SteamTur-EXT-WO-20_29) were installed in order to comply with 2020 goals.

In connection with chapter 5, where this technology was identified as most optimal, it is visible that Balmorel, through use of its features of operation and investments optimisation, has also made a selection of this technology to be installed in the power system. It is a proof then that both high efficiency and low cost were the conditions for choice by the tool.

The total CO_2 emissions in "BAU 2020" scenario (see figure 6.9) amounted to 160.19 Mt, with the highest contribution from coal and lignite, use of which will continue at least in the near future. When compared to 2010 scenario, emissions grow due to increased coal usage.

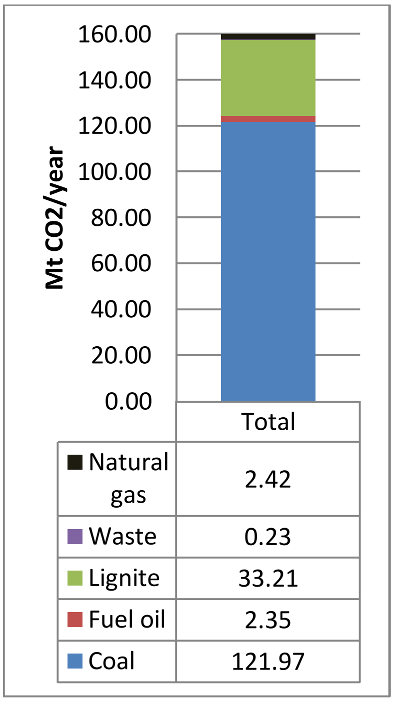


Figure 6.9 CO_2 emissions in "BAU 2020" scenario

6.3.3 Sum – up and conclusions

The aim of this analysis was to show results of constructing the scenario of the 2020 electricity system that can serve as a reference to compare it with the two alternative scenarios for the same year. In terms of electricity production, the created model seems to be working, there are some differences, but it is decided to be used as a reference for further 2020 analyses.

The discrepancies that occurred concerned the current scenario and the Action Plan data, especially larger biomass production and lower coal production than expected. It is most probably caused by inability of the model to use installed coal combustion units due to area restrictions and invest in biomass instead. The differences in biogas and wind production can be again justified by technology type and age differences.

As expected, the Balmorel model identified the extraction wood chip – fired CHP as the best solution, which correlates with results of electricity costs calculation in chapter 5. Due to the introduction of new biomass units on wood chips, the overall average electrical efficiency increased by 3% in comparison to 2010. The total CO_2 emissions in "BAU 2020" scenario amounted to 160.19 Mt, which means a growth in comparison to 2010 scenario, because of increased coal combustion.

6.4 Scenario “Efficient BAU 2020”

This chapter will present the second of 2020 scenarios, which aims at replacing all biomass plants with completely new in 2020.

This scenario shows the consequences of using in 2020 only newly installed biomass plants to comply with the goals stated in (NREAP 2010) and (Ministry of Economy 2009).

6.4.1 Scenario assumptions

All the assumptions are as in the “BAU 2020” scenario (section 6.3), except for:

- All old solid biomass – combustion units will be replaced by new capacities, installed to comply with the goal of 17% of renewables in electricity generation in 2020.
- The table 6.12 shows the types and amounts of installed technologies.

Table 6.12 Technologies installed in the “Efficient BAU 2020” scenario

Technology	Total installed capacity (MW)
Hydro run – off – river	1152
Solar photovoltaic	3
Wind onshore	5875
Wind offshore	500
Biogas	980
Solid biomass old capacities	0
Solid biomass new capacities	1604
TOTAL biomass	1604

6.4.2 Modelling results and analysis

The modelling results and the analysis for “Efficient BAU 2020 “scenario will be provided.

As can be seen in the table 6.13 the electricity generation in Poland in this 2020 scenario is the same as in “BAU 2020”, equalling to 202.83 TWh, out of which biomass represents 11.06 TWh.

Table 6.13 Electricity generation in “Efficient BAU 2020” scenario

Type of fuel	Production (TWh)
Coal	129.42
Lignite	35.63
Municipal waste	0.22
Natural gas	2.71
Solar	0.00
Hydro	2.97
Wind	15.48
Biomass	11.06

Biogas	5.34
TOTAL	**202.83**

Below, in the figure 6.10, two diagrams are set together: for "BAU 2020" (reference scenario) and the current scenario "Efficient BAU 2020".

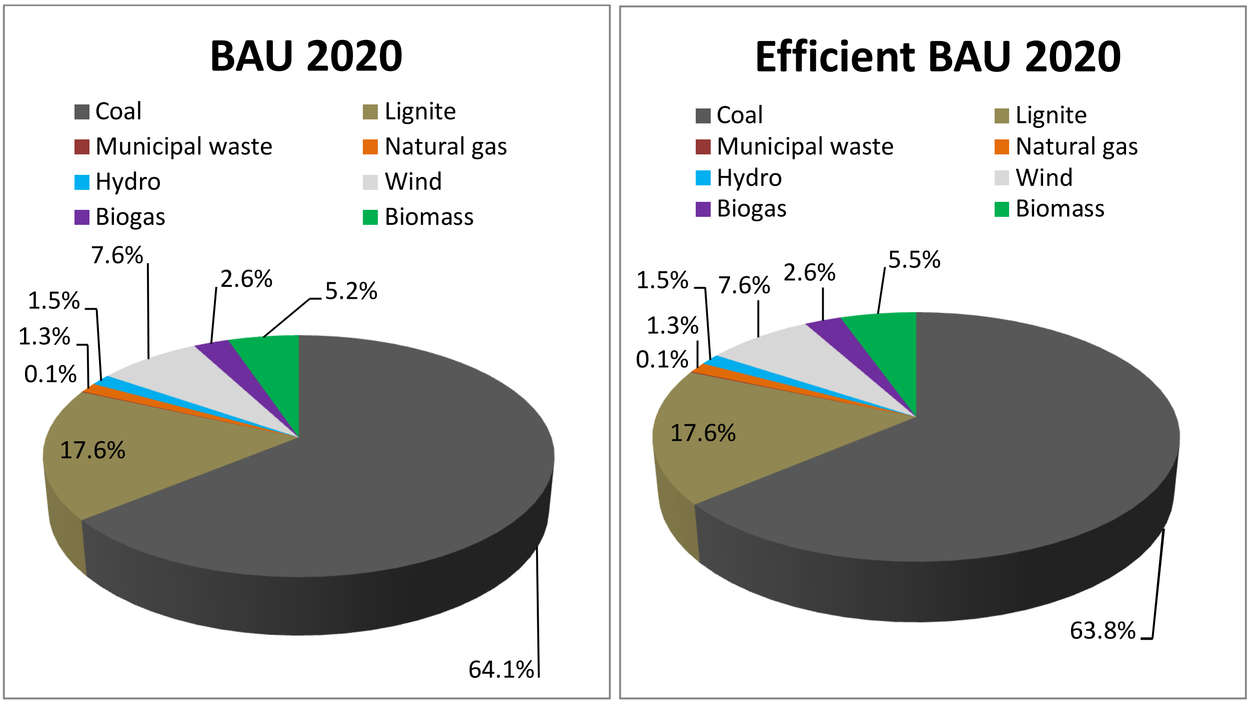


Figure 6.10 Comparison of the scenarios "Efficient BAU 2020" and " BAU 2020"

It can be observed from the above figure that renewables in both scenarios contribute to 17% of electricity generation, the rest of the production provided mainly by coal and lignite. The production from all renewable sources and lignite is identical in both cases, but a difference is seen in case of biomass and coal – based electricity production. In "Efficient BAU 2020" biomass contribution increases by 0.3%, while coal decreases by the same share, in comparison to reference. Thus, it is impossible to state for sure, if it was caused by changing units and their efficiency or the modelling assumptions.

A similar number of new biomass CHPs as in the reference was previously projected to be installed, in order to state easily whether an increased electrical efficiency could have some influence on the system.

One of the reasons of 0.3% higher biomass share than in the reference may be similar issue of the modelling as in the previous chapter: the model was made to invest only in biomass extraction plants, choosing between two types, as well as fitting them in the right heat areas, where demand exists. However, regarding coal, since the model could not use more capacities than those installed exogenously (externally, not as a model calculation) in a few areas, it resulted in investing in the increased amount of biomass plants in the areas where demand existed, but no new coal capacities were installed. Simply because more units were decommissioned in this scenario than in "BAU 2020" (the old biomass units), this issue appeared in more areas, causing larger investments in biomass and larger production on this type of fuel.

Additionally, since the model was investing in extraction units that produce heat and electricity, completely new investments and types of plants may have influenced the flow of heat in areas, also causing installing increased unit capacity.

However, the fact itself of implementing new efficient plants in "Efficient BAU 2020" scenario was achieved; the table 6.14 demonstrates that the average electricity efficiency has increased by 14% from 33% in the reference, because all of the old biomass plants are replaced with extraction units, fired by wood chips:

Table 6.14 Electrical efficiency of biomass units in "Efficient BAU 2020"

Unit name	Electrical efficiency
SteamTur-EXT-WO-20_29	0.47

The CO_2 emissions in this scenario (see figure 6.11) amounted to 157.3 Mt, with the highest contribution again from coal and lignite. They are lower than in the "BAU 2020" scenario, by approximately 3 Mt. However, this result has to be taken with caution, because the biomass share is higher in this scenario than in the reference "BAU 2020", but it cannot be claimed that this has happened due to installing new plants, but simply different fuel share.

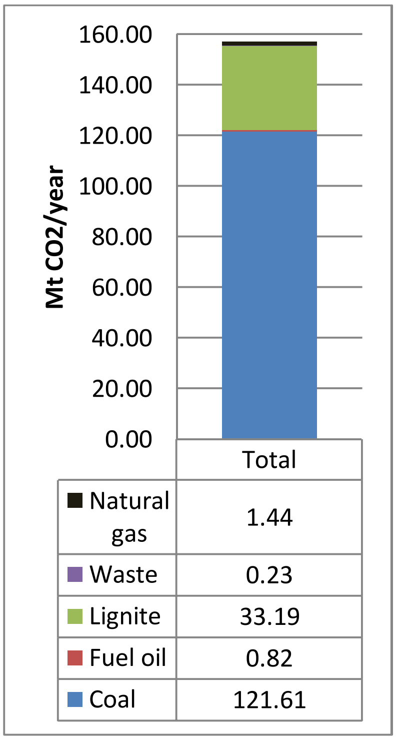


Figure 6.11 CO_2 emissions in "Efficient BAU 2020" scenario

6.4.3 Sum – up and conclusions

The aim of this analysis was to show results of constructing the scenario of the 2020 electricity system that can serve as an example of a system in 2020 with only new biomass units and to compare it with the reference scenario for the same year. In terms of electricity production, the created model seems to be working, but some differences occur, that make it difficult to assess some of the impact of this scenario.

The discrepancies that occurred concerned larger biomass production and lower coal production than expected, which are not necessarily connected with what had been expected to achieve in this scenario. It can be seen, that the coal – based electricity generation and CO_2 emissions are lower than in reference, as well as biomass – based generation is higher. It is most probably caused by inability of the model to use installed coal combustion units due to area restrictions and causing it to invest in additional biomass units instead.

Due to the decommission of old biomass plants and introduction of only new wood chip – fired extraction units the average electrical efficiency increased by 14% in comparison to 2020 reference. The total CO_2 emissions in "Efficient 2020" scenario amounted to 157.3 Mt, which means a small decline in comparison to "BAU 2020" scenario, because of decreased coal utilisation.

6.5 Scenario "New biomass 2020"

This chapter will present the third and final of 2020 scenarios, which aims at not only replacing all biomass plants with completely new in 2020, but also installing additional ones. This is done to analyse the influence of increased biomass usage in the Polish energy system.

6.5.1 Scenario assumptions:

All the assumptions are as in the "BAU 2020" scenario (section 6.3), except for:

- All RES technologies are as the BAU 2020 scenario, but an additional amount of biomass units is installed in the system, to provide twice as much electricity as the official goal, namely 34%. The table 6.15 shows the types and amounts of installed technologies.

Table 6.15 Technologies installed in the "New biomass 2020" scenario

Technology	Total installed capacity (MW)
Hydro run – off – river	1152
Solar photovoltaic	3
Wind onshore	5875
Wind offshore	500
Biogas	980
Solid biomass old capacities	0
Solid biomass new capacities	6122
TOTAL biomass	6122

6.5.2 Modelling results and analysis

The modelling results and the analysis for "New biomass 2020 "scenario will be provided.

As can be seen in the table 6.16 the electricity generation in Poland in this 2020 scenario was the same as in all scenarios for 2020 and amounted for 202.83 TWh. Biomass utilisation increased and represents 45.02 TWh.

Table 6.16 Electricity generation in "New biomass 2020"scenario

Type of fuel	Production (TWh)
Coal	95.98
Lignite	35.32
Municipal waste	0.22
Natural gas	2.49
Solar	0.00
Hydro	2.97
Wind	15.48
Biomass	45.02
Biogas	5.34
TOTAL	**202.83**

Below in the figure 6.12, two diagrams are set together: "BAU 2020" (reference scenario) and the current scenario "New biomass 2020".

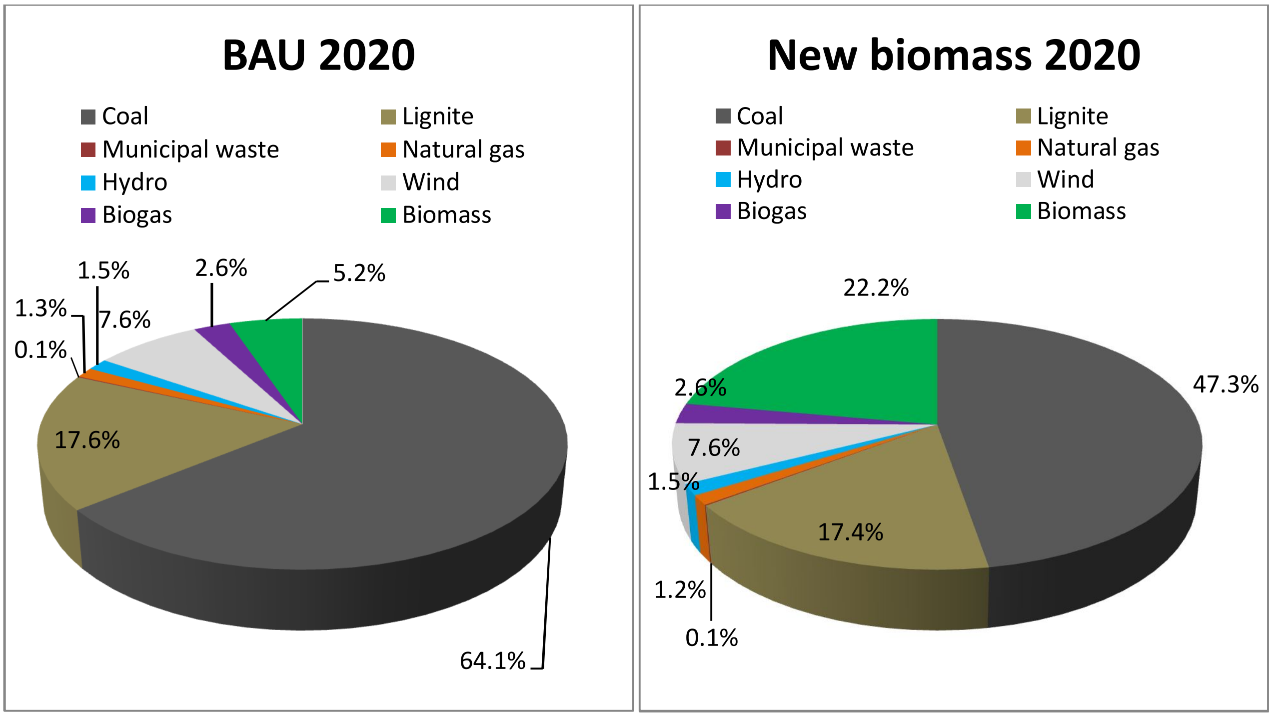


Figure 6.12 Comparison of the scenarios "BAU 2020" and "New biomass 2020"

It can be observed from the above figure 6.12 that renewables in the first scenario contribute with approximately 17% of electricity generation, while it is almost doubled in "New biomass" scenario. Other RES produce the same, while biomass increases its share by 17%, but most of generation (64.7%) is still provided mainly by coal and lignite. Interestingly, although no changes were applied to lignite or natural gas units, their production decreases by 0.1% each, which in case of natural gas may be caused by high price and in case of lignite – high emissions of pollutants. Therefore it was more optimal to invest and use new biomass units than those fuels in some cases, which was a choice made from the point of view of Balmorel features of and operation and investment optimisation.

When it comes to the changes in biomass plant efficiencies in "New biomass 2020" scenario, the table 6.17 demonstrates that they have increased by 14% in comparison to reference, as all of the old biomass plants are replaced with extraction units, fired by wood chips.

Table 6.17 Electrical efficiency of biomass units in "New biomass 2020"

Unit name	Electrical efficiency
SteamTur-EXT-WO-20_29	0.47

The CO_2 emissions in "New Biomass 2020" scenario (see figure 6.13) amounted to 120.16 Mt, with the highest contribution again from coal and lignite. This 33% decrease (40 Mt) in comparison with BAU 2020 is due to a significant increase of utilisation of biomass that allows replacing coal and is the most optimal of all the modelled scenarios, even 2010.

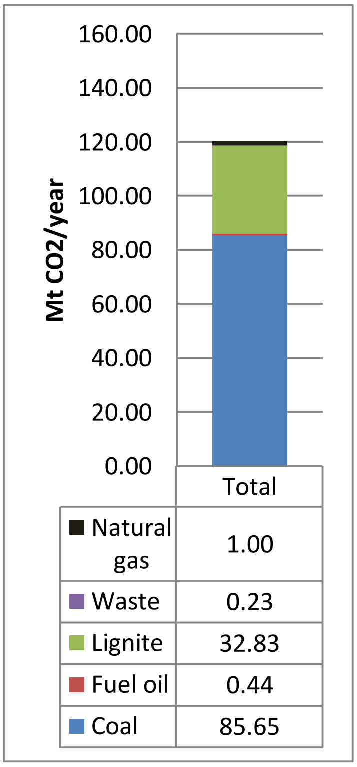


Figure 6.13 CO_2 emissions in "New biomass 2020"

6.5.3 Sum – up and conclusions

The aim of this analysis was to show results of scenario of the "New biomass 2020" electricity system and to compare it with the reference scenario "BAU 2020" for the same year. In terms of electricity production, the created model seems correct, although there are some minor differences that had not been anticipated.

As the aim of the scenario is to show the influence of increased biomass utilisation, this goal was achieved by implementing new biomass units that generate electricity, increasing biomass share by 17% and overall RES share by about 34%. Due to the implementation of new biomass extraction units the average electrical efficiency of increased by 14% in comparison to 2020 reference, staying the same as in the previous scenario.

The total CO_2 emissions in "New biomass 2020" scenario decreased to 120.16 Mt, which means a significant improvement in comparison with the "BAU 2020".

The discrepancies that occurred in lignite and natural gas production levels although no changes were applied to those units may be caused by the model's partial equilibrium and operation and investment optimisation, that avoids high price, but also high emissions of pollutants.

6.6 Summary and comparison of scenarios

The main criteria of assessment will be depicted and compared. This will be done in order to see how the technical conditions of scenarios were fulfilled and whether the results were as assumed before modelling.

The results for all the 2020 scenarios are outlined in the following table 6.17 according to the scenario assessment criteria:

- Electricity generation and biomass share;
- Plant efficiencies;
- CO_2 emissions

Table 6.18 Summary of all modeled 2020 scenarios

Criteria	Scenario		
	BAU 2020	Efficiency 2020	New Biomass 2020
Total electricity generation (TWh)	202.83	202.83	202.83
Generation from biomass	10.54 (5.2%)	11.06 (5.5%)	45.02 (17%)
Average electrical efficiencies	0.33	0.47	0.47
CO_2 emissions (Mt)	160.19	157.30	120.16

The total electricity generation and the generation from wind, hydro, biogas is identical in all the scenarios. The biomass generation is the highest in the third scenario, where it contributes with 17% of total production of electricity. The comparison shows that from the altogether points of view of biomass share in the system, electrical efficiency and CO_2 emissions, the most optimal 2020 scenario is "New biomass 2020". It is however difficult to compare "BAU 2020" with "Efficient BAU 2020", as some differences in production appear, so even though it demonstrates more positive effects, it to be taken with caution.

All in all, although some of the results are not as was anticipated before modelling, it is considered that they are still worth to be taken further for the analysis of socio – economic consequences in the chapter 7.

7 Socio – economic consequences and implementation conditions

This chapter consists of two main parts. The first part will demonstrate results of calculation and analysis of selected socioeconomic consequences of 2020 scenarios in the areas of employment and state budget of Poland. The second, will concern the barriers and implementation conditions for the modelled scenarios.

As it was described in more detail in the chapter 1, the focus of the thesis is to improve the efficiencies and increase the amount of biomass used in the Polish energy system in 2020, whilst manifesting changes in employment and state budget. In the chapter 6, the technical approach was shown in the form of technological scenarios. Their socio – economic consequences are part of institutional and political theoretical approach, as it is explained in the figure 7.1 below.

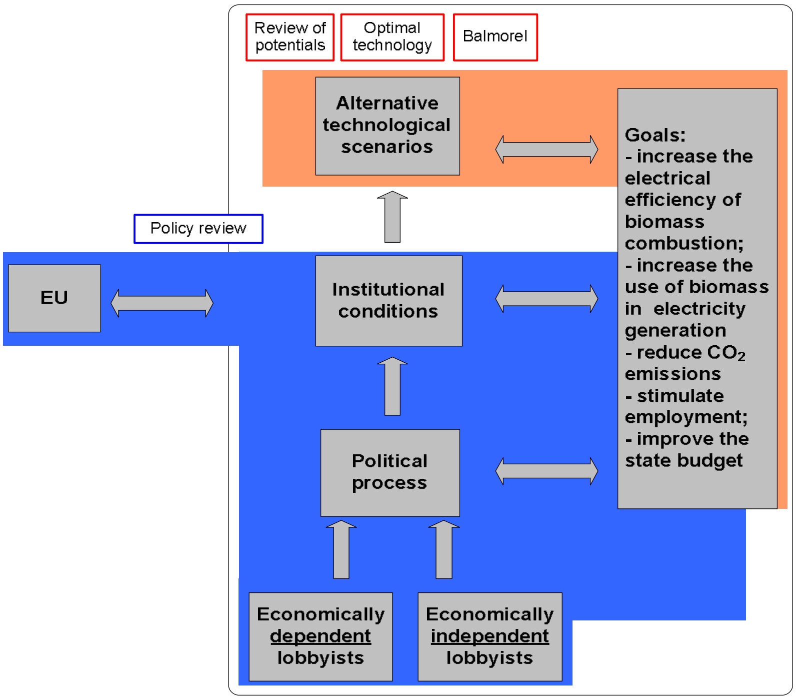


Figure 7.1 Theoretical approach to chapter 7

More specifically, the institutional and political theoretical approach of the chapter is to demonstrate what the socioeconomic consequences of the modelled scenarios will be, in terms of employment and state budget, as well as to demonstrate implementation conditions of the increased biomass utilisation in 2020.

7.1 Socio – economic consequences

This subchapter will show results of the modelling and additional calculations made in order to discuss consequences of 2020 scenarios in the areas of employment and state budget in Poland.

All the results for specific 2020 scenarios are discussed in subchapters. For a more thorough description of each scenario, see chapter 6.

7.1.1 Scenario "Business as usual 2020 (BAU 2020)"

This is a scenario that aims at representing situation in Poland in 2020, if the current policy is continued. This means complying with the Action Plan, but only to the limited required level, in order to avoid any penalties that could possibly be imposed.

7.1.1.1 Assumptions

The following assumptions were made:

- The time period of calculation is 10 years. Such period was chosen, since it was decided to compare also the older biomass units from "BAU 2020" scenario with others scenario, which after 10 years might be decommissioned.
- For simplifying the calculations, the costs are not discounted.
- Average operation and maintenance costs of old units producing biomass are also added in the BAU 2020 scenario.
- Capacities of newly installed units and their production are given by the model. Total investment and operation and maintenance costs for the year of 2020 are also calculated by the model.
- For new wood – chips fired extraction units the investment cost is 1.6 million EUR/MW, the fixed O&M is 26 000 EUR/MW/year, variable O&M is 3.2 EUR/MWh. For the previously existing units an average is calculated from all plants, resulting for the fixed cost of 24 000 EUR/MW and the variable cost of 5 EUR/MWh.
- Calculations of amount of employment resulting from the new biomass investments are based only on the direct employment expected in building and O&M of new biomass units and not other sectors like direct biomass production, harvesting and transport. Thus the resulting numbers are only a part of the employment increase caused by biomass investments.
- Employment calculations are based on assumed domestic share of investment and O&M costs.
- Investment import share of the biomass CHP investments is 50%, because while there are Polish companies specialising in designing and building complete units for energy sector (among them the one of the largest in Europe), many boilers are imported.
- Import share of operation and maintenance cost for newly installed capacities is 25%, since most of the services and actions incurring this cost will be from Poland.
- Import share of operation and maintenance of the existing units is 15%, as those technologies are already known and even more of the services and actions are Poland – based.
- The other RES sources investments are not taken into consideration, as they remain the same in all the 2020 scenarios.

7.1.1.2 Methodology for calculations and results

Investment and O&M costs

The table 7.1 below demonstrates the cost structure of already existing and newly installed biomass technologies in scenario "BAU 2020".

Table 7.1 Investment and O&M costs in scenario " BAU 2020"

Technology type	Wood chip CHP	Old biomass units
Capacity [MW]	854	719
Production [MWh/year]	5 730 000	4 810 000
Total investment cost [EUR]	1 366 400 000	-
Fixed O&M cost [EUR/year]	22 204 000	17 256 000
Variable O&M cost[EUR/year]	18 336 000	24 050 000
Yearly total O&M [EUR]	40 540 000	41 306 000

Since the generation of biomass in the "BAU 2020" scenario consists of both existing and new units, it was deemed necessary to take into consideration also the operation and maintenance cost of old units. The table 7.1 above presents the capacity, production, total investments cost and O&M costs, divided for old and new units. It is visible that old units have lower fixed costs (the technology is better known and less demanding), but higher variable costs due to e.g. unexpected breakdown that may often happen in older units.

Poland's state budget and employment

The table 7.2 below demonstrates results of calculation

Table 7.2 Calculation of employment and state budget revenue in scenario "BAU 2020"

Domestic investment cost [EUR]	683 200 000
Domestic total O&M cost of new units[EUR/year]	30 405 000
Domestic total O&M cost of new units in 10 years [EUR]	304 050 000
Domestic total O&M of old units	35 110 100
Domestic total O&M of old units in 10 years [EUR]	351 101 000
Sum of investment and total O&M [EUR]	1 338 351 000
Average yearly salary gross [EUR]	9 696
Salary minus personal allowance [EUR]	8 923
Amount of full – time employments during 10 years	149 989
Tax rate	18%
Total contribution to the state budget in 10 years (MEUR)	240.9

To calculate employment and state budget, a domestic share of 50% is applied to investment cost of new units. Next, a 75% share is applied to new units' O&M costs, and multiplied by 10 years of operation. Then, an 85% share is applied to the existing unit's O&M and multiplied also by 10 years. The old and new units' O&M costs are summed up with the investment. Next, the total amount is divided by the average yearly gross salary of 9696 EUR, resulting in the amount of full – time jobs generated during the 10 year - period, amounting for 149 989. The total contribution to the state budget from taxes is calculated as yearly salary gross minus the personal allowance of 773 EUR times amount of employments times the taxes and equals 240.9 million euro.

7.1.2 Scenario "Efficient BAU 2020"

This is a scenario that aims at representing situation in Poland in 2020, if the old biomass capacities are not in use anymore in 2020, thus resulting in a necessity of installing completely new units in accordance to (NREAP 2010).

7.1.2.1 Assumptions

The assumptions are the same as in the previous scenario, however additionally:

- The old biomass electricity generating capacities are decommissioned, with 1604 MW of new biomass units installed in 2020.

7.1.2.2 Methodology for calculations and results

Investment and O&M costs

The table 7.3 below demonstrates the capacity, production, total investments cost and O&M costs, for all newly installed wood chip CHPs.

Table 7.3 Investments and O&M costs in scenario "Efficient BAU 2020"

Technology name	Wood chip CHP
Capacity [MW]	1604
Production [MWh/year]	11 060 000
Total investment cost [EUR]	2 566 400 000
Fixed O&M cost [EUR/year]	41 678 000
Variable O&M cost[EUR/year]	35 392 000
Yearly total O&M [EUR/year]	77 070 000

This scenario has only newly installed capacities that amount for higher costs than in the previous one.

Poland's state budget and employment

The table 7.4 below demonstrates results of calculation

Table 7.4 Calculation of employment and state budget revenue in scenario "Efficient BAU"

Domestic investment cost [EUR]	1 283 200 000
Domestic total O&M cost [EUR/year]	57 802 500
Total O&M in 10 years [EUR]	578 025 000
Sum of investment and total O&M [EUR]	1 861 225 000
Average yearly salary gross [EUR]	9 696
Salary minus personal allowance [EUR]	8 923
Amount of full – time employments during 10 years	191 958
Tax rate	18%
Total contribution to the state budget in 10 years (MEUR)	308.3

The methodology for calculation of employment in this scenario is similar to the one in previous scenario. The only difference is the fact that no old biomass capacities are operating here, so only 1604 MW of new capacities are used as a basis for further calculations.

Thus, a domestic share of 50% is applied to investment cost and a 75% share to O&M costs. The O&M costs are multiplied by 10 years of operation. The O&M costs are summed up with the investment. Next, the total amount is divided by the average yearly gross salary of 9696 EUR, resulting in the amount of full – time jobs generated during the 10 year - period, amounting for 191 958. The total contribution to the state budget from taxes is calculated as yearly salary gross minus the personal allowance of 773 EUR times amount of employments times the taxes and equals 308.3 million euro, higher than in the "BAU 2020" scenario.

7.1.3 Scenario "New biomass 2020"

This is a scenario that aims at representing situation in Poland in 2020, if the old biomass capacities are replaced by new units in 2020 and additional number of new plants is built to exceed goals in (NREAP 2010).

7.1.4 Assumptions

The assumptions are the same as in the BAU 2020 scenario, however additionally:

- Not only the old biomass electricity generating capacities are decommissioned, but 6122 MW of new biomass units are installed in 2020.

7.1.4.1 Methodology for calculations and results

Investment and O&M costs

The table 7.5 below demonstrates the capacity, production, total investments cost and O&M costs, for all newly installed wood chip CHPs.

Table 7.5 Investments and O&M costs in scenario "New biomass"

Technology name	Wood chip CHP
Capacity [MW]	6 122
Production [MWh/year]	45 020 000
Total investment cost [EUR]	9 795 200 000
Fixed O&M cost [EUR/year]	159 172 000
Variable O&M cost[EUR/MWh]	144 064 000
Yearly total O&M [EUR/year]	303 236 000

As the scenario with the highest number of newly installed woodchip CHPs, it has the highest costs.

Poland's state budget and employment

The table 7.6 below demonstrates results of calculation.

Table 7.6 Calculation of employment and state budget revenue in scenario "New biomass"

Domestic investment cost [EUR]	4 897 600 000
Domestic total O&M cost [EUR/year]	227 427 000
Total O&M in 10 years [EUR]	2 274 270 000
Sum of investment and total O&M [EUR]	7 171 870 000
Average yearly salary gross [EUR]	9 696
Salary minus personal allowance [EUR]	8 923
Amount of full – time employments during 10 years	739 673
Tax rate from salaries	18%
Total contribution to the state budget in 10 years (MEUR)	1 188 .0

The methodology for calculation of employment in this scenario is similar to the one in previous scenario.

A domestic share of 50% is applied to investment cost and a 75% share to O&M costs. The O&M costs are multiplied by 10 years of operation. The O&M costs are summed up with the investment. Next, the total amount is divided by the average yearly gross salary of 9696 EUR, resulting in the amount of full – time jobs generated during the 10 year - period, amounting for 739 673. The total contribution to the state budget from taxes is calculated as yearly salary gross minus the personal allowance of 773 EUR times amount of employments times the taxes and equals 1 188 million euro, the highest of all scenarios.

7.2 Summary and conclusion of results

This chapter will reiterate the main results that were extracted from the socio – economic analysis.

The table 7.7 below depicts the main results of socio – economic calculations in the chapter 7.

Table 7.7 Summary of results of socio – economic calculations

Criteria	BAU 2020	Efficient BAU 2020	New biomass 2020
Employment over a 10 year period (full – time jobs)	149 989	191 958	739 673
Contribution to state budget [MEUR]	240.9	308.3	1 188 .0

It is noticeable from the table, that the most optimal scenario is "New biomass", generating much more full – time employments in the period of 10 years than the remaining two scenarios. It also has the highest contribution to the state budget in that timeframe.

Taking into consideration the increasing unemployment rate in Poland, any possibility of improving the situation is valid. As in 2009 there were approximately 1 900 000 unemployed in Poland, especially the "new biomass scenario would help tackling the problem, decreasing it by approximately 4% yearly.

In terms of state budget revenues, it is visible that the investments needed would generate a lot of income, but also the scope of them is significant. When compared to the real state budget revenues, the amounts may not seem very realistic, but they demonstrate how the biomass investments are able to speed - up Polish economy.

8 Main actors, legislation and implementation conditions

This chapter will provide an analysis of the main actors of biomass sector in Poland and their global, macro- and microstructure. Moreover, the role of specific organisations, institutions and individuals will be explained in microstructure. Additionally, legislation within the subject of the research question will be described, as well as technical, institutional and political barriers for implementation.

The focus of the chapter is on the institutional and political conditions required for changes in the Polish biomass sector, in accordance with the problems identified and whilst considering the goals shown in the figure 8.1 below.

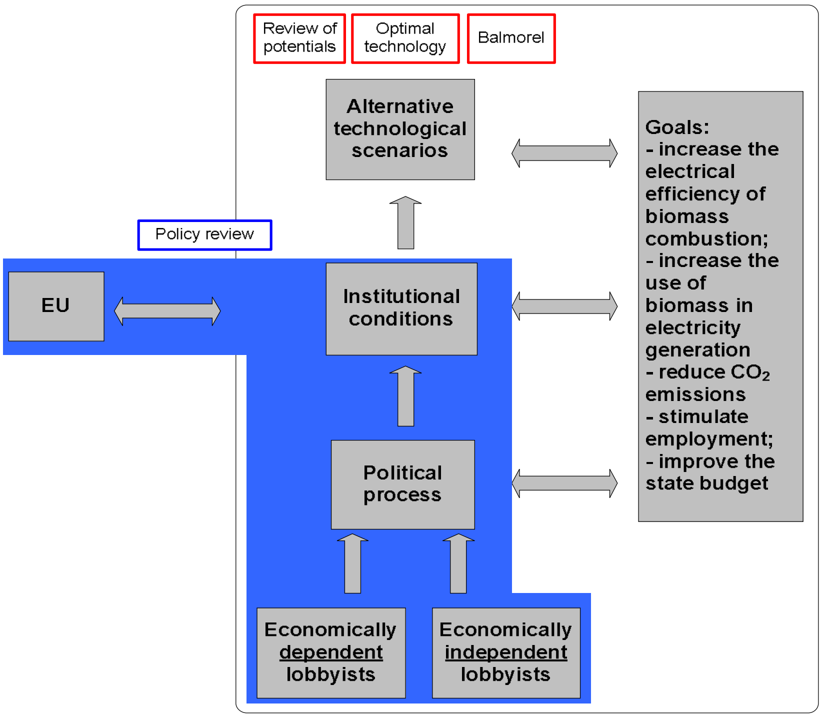


Figure 8.1 Theoretical approach to chapter 8

Such analysis is made possible through identifying a global, macro- and microstructure in the Polish energy system with a focus on biomass, which is done in the subchapters 8.1 – 8.3 below. Furthermore, the policy in the sector is examined in subchapter 8.4, and technical, institutional and political implementation barriers are investigated in subchapter 8.5.

8.1 Global structure

This structure will concern all the actors, organisations and institutions that play a (more or less significant) role in biomass sector in Poland.

In order to reach a better understanding of current structure of the Polish biomass sector it is useful to conduct a detailed theoretical analysis through a global, macro- and micro approach. In the range of an area such as biomass energy sector, different actors, institutions and legislation exist, thus performing an adequate global-structure analysis depends on the available knowledge regarding this area. The word **global** accentuates the overall approach of the present energy system in terms of biomass usage and tries to incorporate all the key players from this framework (Hvelplund 2001).

The figure 8.2 below highlights all the components deemed necessary in order to achieve an adequate level of aggregation.

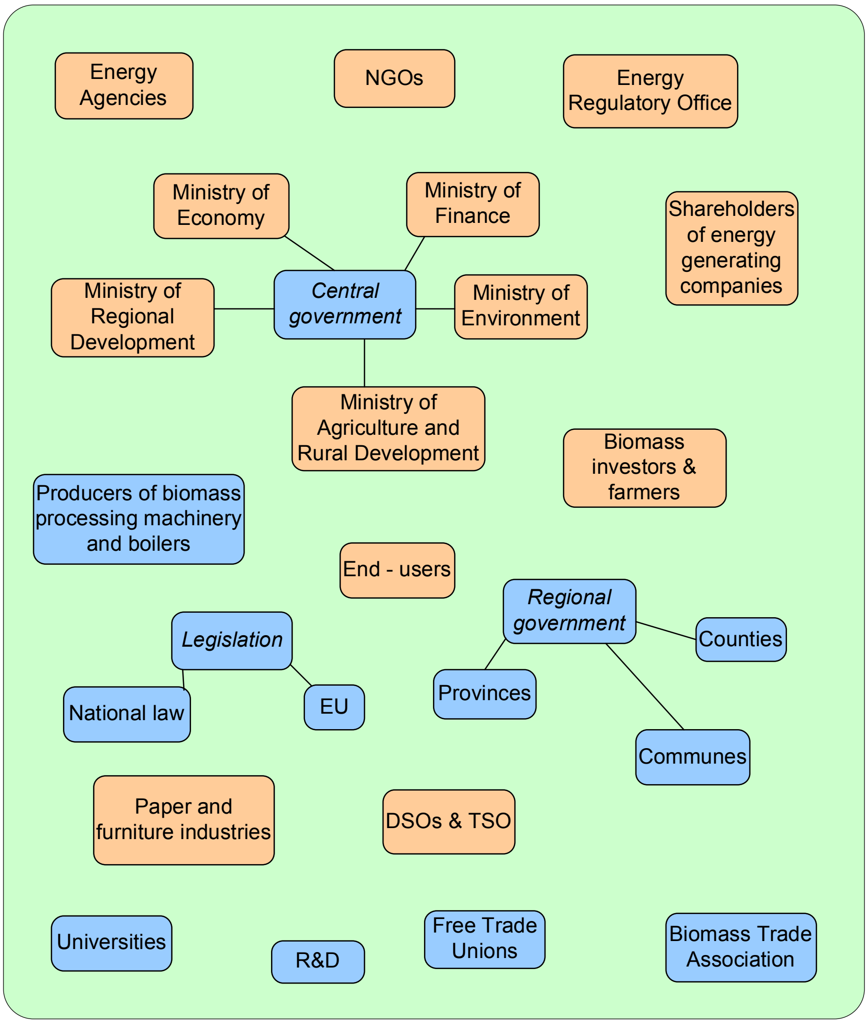


Figure 8.2 The analytical global structure

The actors mentioned in the figure 8.2 play some role in the current energy system in relation to the research question. They have various levels of knowledge, rules and are involved to a different degree, as well as their decision power and implementation strategies differ. Moreover, certain actors (marked in orange) have more influence than others and they will be set further into macro – and microstructure.

8.2 Macrostructure

The macro-structure analysis will depict selected most important and relevant actors present in the global framework.

The most important and relevant components defined in the global framework are further selected to be presented in the framework of the macro-structure. Thus, the main actors, organizations and institutions with the largest influence and power decision in the Polish biomass sector are depicted in the figure 8.3 below.

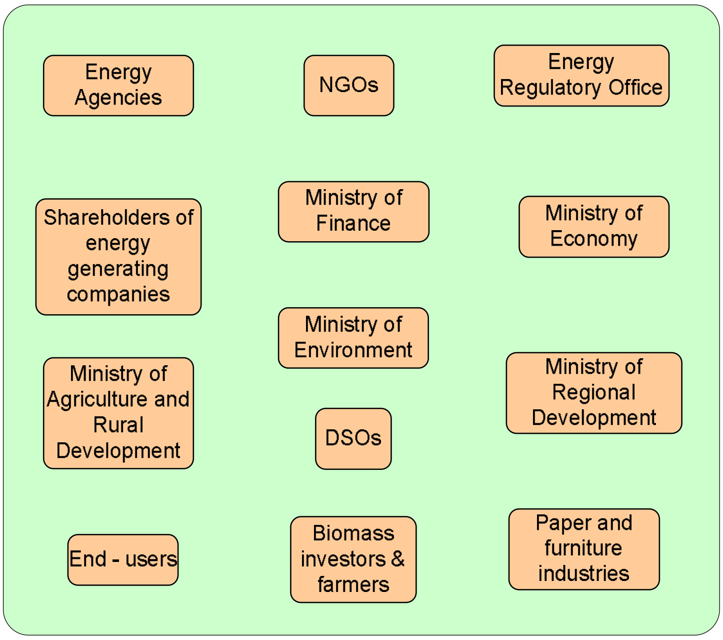


Figure 8.3 The analytical macrostructure

The reasons for choice of those actors in the analytical macrostructure are shown in the table 8.1 below:

Table 8.1 Actors chosen for macrostructure

Actor	Reasons for inclusion
Energy Agencies	Through promoting renewable energy and energy efficiency, they play a role in enhancing dialogue between actors in the energy market
NGOs	They are against increased biomass utilisation because they consider forest biomass use to cause deforestation in Poland and energy crops cultivation to decrease biodiversity.
Energy Regulatory Office	As main energy regulatory body, it can enhance competition and transparency in the market.
Shareholders of energy companies	They decide on the investment strategy of the energy companies.
Ministry of Finance	Distributes money from funds and bares consequences of changes in state budget.
Ministry of Economy	Has a department of energy that sets policy in that area.
Ministry of Agriculture and Rural Development	Interested in promoting rural development and agriculture.
Ministry of Environment	Interested in measures protecting the environment.
Ministry of Regional Development	Plays a role in the spatial development legislation.
DSOs	Play a role in the energy supply planning.
Biomass investors and farmers	They aim at improving their profit, so are interested in increased biomass usage.
The paper and furniture industries	For those industries specific type of wood (forest) is essential, so they are against the use of forest - based wood by energy generators, because it causes raw biomass prices to rise significantly and increase their costs.
Final end - users	Through free choice of energy supplier, they can influence the strategy of the energy companies shareholders

8.3 Microstructure

The micro level will present a more in - depth insight to all the actors included in the macro level and will try to illustrate their relevant features, such as attributes and positions in the energy system and interdependencies among them, in view of author's personal understanding and theoretical design of the situation in the biomass sector.

The macrostructure presented the most influential actors, which are presented in more detail in the microstructure, along with some connections among the actors. The described role of the actors in the microstructure is as regarded in the author's theoretical design of the situation in the biomass sector.

8.3.1 Energy Agencies

Before EU accession, there existed a few regional organisations promoting energy efficiency in Poland. Later, due to the EU's Intelligent Energy Europe programme a possibility arose for creating more of them. Recently they started more dynamic and visible actions, for example organising conferences for wide public and national fora of agencies. Currently, there are 10 regional and 3 central energy agencies in Poland (EC - Energy 2011).

Their role is crucial, because they aim at promoting renewables, enhancing the importance of RES in the society and helping find means of support from the EU, state and region for investors etc. Therefore they have a power to influence energy final end – users, ministries and their legislation, as well as biomass investors to facilitate transition to biomass.

8.3.2 NGOs

Since the 1990's, there has been a number of NGOs in Poland acting within ecology and biodiversity. Some also get involved into climate and renewable energy issues, not agreeing to the policy of the Ministry of Economy allegedly supporting only forest biomass combustion. Those NGOs are against increased biomass utilisation because they consider forest biomass use to cause deforestation in Poland and energy crops cultivation to decrease biodiversity (Greenpeace Polska 2011).

As environmental NGOs, such institutions have an impact on the mind – sets of energy users, but also the ministries, which are dependent on the general public's opinion on their policy.

8.3.3 Energy Regulatory Office

The Energy Regulatory Office (ERO) is an independent energy regulatory institution managed by its President. The main tasks of ERO include: issuing and withdrawing concession for electricity and/or heat production, verifying and accepting tariffs for gas, electricity and heat, administering green certificates and substitute fees (see section 8.4), consulting development plans of energy companies, choosing electricity and gas TSO and DSOs, promoting competition in the market and protecting the individual energy users, as well as gathering statistics on electricity price and renewables (Energy Regulatory Office 2011).

The Energy Regulatory Office has a power to improve the transparency in the market and enhance competition and liberty to choose the electricity supplier, while it interacts with energy end – users, generation companies, TSOs and DSOs, as well as with the central government.

8.3.4 Shareholders of energy companies

There are many energy generating units in the Polish market, but most of them belong to large companies, such as Polska Grupa Energetyczna (PGE), Tauron, Energa or Enea, with state holding varying amount of shares in them. Units generating from RES belong to smaller firms or also the large ones (ARE 2010).

The majority of power plants in Poland are coal – fired, thus there is a strong will of those energy companies dominating the market to exploit their plants as long as it is possible and not invest unless it is absolutely necessary. It is understood that there are mutual interdependencies between the companies and the government, which may prevent any changes. Additionally, it is noticeable that in some cases employees holding positions in ministries are transferred to be part of management of the energy groups or coal mines, which may also imply too strong connections between the state and energy sector (Gazeta.pl Gospodarka 2011).

Except for the aforementioned examples of connections, the energy companies have contact mainly with the Energy Regulatory Office, as well as DSOs (structurally independent, but partly owned by the companies) and biomass producers (e.g. farmers or pellet producers).

8.3.5 Ministry of Finance

The Ministry of Finance acts within the areas of state budget, public finance and financial institutions. The Ministry prepares, executes and controls the state budget, administers financing of local governments and manages the public debt, manages incomes and expenses of the state, as well as has tasks within operation of financial markets (Ministry of Finance 2011).

It is an important actor, because it can administer new funds for biomass renewables. Moreover, in case of any changes in the market caused by implementing new scenarios, the trade balance and state budget will be influenced, so the Ministry has to manage the resources accordingly.

The Ministry of Finance collaborates with other ministries in terms of funds disposition, biomass investors (through administered EU programmes and other financial support), energy companies (through e.g. taxes) and the Energy Regulatory Office (through e.g. green certificate/substitution fee).

8.3.6 Ministry of Economy

The Ministry of Economy plays a very significant role in the structure, because of its dual responsibilities. Not only is it the most important state administrative institution for the economic policy formation in Poland, but because there is no Ministry of Energy in Poland, it is the Ministry of Economy that manages most of the area of energy.

Its departments directly related to energy sector are: energy, mining, gas and oil, nuclear energy. The Ministry also administers indirectly related areas such as economy law (important e.g. for investors and private persons), as well as forms an intermediary organ for the EU Operational Programmes and state funds, *de facto* administered by smaller units, such as National Fund for Environmental Protection and Water Management (Ministry of Economy 2011).

The Ministry sets a goal for Poland to secure a sustainable future and rationally and effectively use available resources, treating security of supply and environment as two strategic directions. The Ministry of Economy sees RES as an alternative for fossil fuels, but, except for the numbers stated in the (NREAP 2010) and the aim of achieving 15% of renewables in the final energy consumption, no other goals regarding RES are set, thus it is understood that the current approach is lead only by the EU requirements (Ministry of Economy 2011).

The Ministry also acts within legislation and promotion of enterprises through innovation, support for investment from the EU and other national funds or other instruments, as well as within the international economic cooperation, with its mission to create "the best in Europe conditions of conducting business "(Ministry of Economy 2011).

It has contacts with remaining ministries (through e.g. common policy and legislation design), as well as biomass investors and energy companies, mainly due to its policy – setting role and management of some investment funds.

8.3.7 Ministry of Environment

Ministry of Environment plays an important role, because it is responsible for Poland's environmental policy and nature protection through framing, administering and coordinating policies related to national environment protection. Its fields of activities include: waste management, forestry, nature protection, climate change, atmosphere protection and water management (Ministry of Environment 2011).

Ministry of Environment is responsible for forestry and can induce more sustainable forest management practices that will allow increasing wood production without harming the environment. It collaborates with other ministries, but especially with Ministry of Agriculture and Ministry of Economy, in terms of measures promoting environmental protection.

(Ministry of Environment & Ministry of Economy 2011) have together created a draft document showing their common strategy on environment and energy in Poland by 2020, which is a valuable source on both Ministries' views and co – operation within Polish energy sector. As much as Polish dependence on coal is admitted, it is justified by the durability of the energy installations and the fact that large part of units was built when environmental requirements were not as important as now. Coal is considered a natural resource allowing the country to maintain lower dependence on energy imports then average in the EU. It is also suggested that the EU policy is too unstable and decreases the possibility of making investment decisions. Although it is agreed that environment and climate protection are also a means for innovation and investments, both Ministries consider the so- called "clean coal technologies" as the most promising and innovative in Polish conditions. Unfortunately, creating more green jobs in the rural areas by promoting development of biomass sector remains at the bottom of the Ministries' agendas.

8.3.8 Ministry of Agriculture and Rural Development

This Ministry contains such departments as land management, rural development, and agricultural markets which are necessary for more optimal biomass implementation into energy sector. It also has a strategic role of creating goals for achieving more sustainable development in rural areas and in that sense it also cooperates with the Ministry of Regional Development (Ministry of Agriculture and Rural Development 2011).

The Ministry of Agriculture and Rural Development is a key actor, because it is responsible for policy in the areas of energy crops and straw. It also collaborates with other ministries, farmers and biomass investors.

8.3.9 Ministry of Regional Development

The Ministry of Regional Development mainly focuses on regions and their development, which is done through implementing specific policy, administering some of the EU funds and taking part in deciding on spatial planning strategies in Poland (Ministry of Regional Development 2011).

One of the important tasks of the Ministry in view of the thesis is the participation in land and spatial development, which may influence for example the localisation of biomass CHPs. Besides, the Ministry co – operates with other ministries, but especially with the Ministry of Agriculture and Rural Development in terms of creating possibilities for improvement of investment and job creation conditions in the countryside.

8.3.10 Distribution Systems' Operators (DSOs)

The electricity DSOs, structurally independent, but owned by four large companies (Enea, Energa, Polska Grupa Energetyczna and Tauron-Polska Energia), manage distribution of electricity in the Polish power system, particularly the functioning, modernisation and development of networks up to 110 kV. They also have an important role in energy supply decisions and local energy planning, because each five years they prepare development plans to satisfy the demand for electricity, each three years – for heat and natural gas and each fifteen years – scenarios for future supply of energy. DSOs are obliged to consult the plans with generators in their area, the gas and electricity TSOs, as well as plans made by communes (in case communes have prepared them). Some of the issues analysed in the plans concern the types and amounts of fuels/energy needed, new investments in units and interconnections and their timeframe, energy efficiency measures etc. (Sejm RP 2011), (CIRE.pl 2007)

The tasks of the DSOs to a certain extent shape the demand for specific energy sources in Poland. It seems that they could be influenced more through communes preparing their plans, which they rarely do, according to (Ministry of Environment & Ministry of Economy 2011). The DSOs made the plans for supply mainly based on the interests of their sister companies (most commonly the large energy generators). In addition, the DSOs need to comply with ERO's regulation, as well as co – operate with biomass energy generators, if they happen to fall within the managed area.

8.3.11 Biomass investors and farmers

Nowadays, most of RES developers in Poland, either Polish or foreign, are interested mainly in wind, biomass and biogas investments. Biomass investors have their thematic association. These key players could be a strong force pushing Poland towards more biomass technology path, but unfortunately, some problems arise. It is mainly large companies that purchase biomass to co-fire with coal, which increases the price of biomass in the market and makes new plant investments less profitable. This biomass and generally RES lobby is still weak and has to compete with the existing large energy companies.

The biomass investors interact mainly with Ministry of Finance and Economy in terms of financial support, as well as with the Energy Agencies – in order to e.g. consult in their planned investments and energy generators, who the farmers sell the product to, or the new unit's developers have to compete with in the market.

8.3.12 Paper and furniture industries

For those industries specific type of wood (forest) is essential, so they are against the ever increasing use of forest-based wood by energy generators, because it causes raw biomass prices to rise significantly and increase their costs. Since the use of paper is gradually increasing, the paper industry will not need it so much, however the furniture manufacturing plays an important role in the Polish economy, because many products are exported.

They do not necessarily cooperate with other actors, but rather compete with energy companies for the fuel. No mutual effort of the NGOs and those industries was noticed; however they have a common interest of reducing forest wood use by the energy sector.

8.3.13 Final end – users

In Poland they constitute approximately 16 million users, with households being about 25 % of the overall electricity market sales (ARE 2010).

However influential, they do not use their right to change electricity supplier that often, but if they did, then, provided they have environmentally – friendly approach, they would be interested in buying rather electricity generated from RES than from fossil fuels.

8.4 Biomass legislation and policy

In this chapter the policy and legislation concerning biomass usage in the energy sector will be presented. An analysis of current policy situation will be conducted in order to understand what influences the current use of biomass in the Polish energy system.

The following selected relevant European and national policy and legislation, as well support schemes were deemed necessary to be described in view of the research question.

8.4.1 European policy

As an EU Member State since 2004, Poland has to comply with laws issued by the European Community. The most important in of the problem formulation are:

- Directive 2009/28/EC of the European Parliament and the Council on the promotion of the use of energy from renewable sources;
- Directive 2004/8/EC of the European Parliament and the Council on the promotion of cogeneration based on a useful heat demand in the internal energy market*;*

The Directive 2009/28/EC sets national targets for renewable energy share in 2020 for each country, in accordance with the overall 20-20-20 goal for the whole EU. Accordingly, each Member State has created a so-called National Renewable Action Plan (NREAP) describing the way the goals will be achieved. Polish target is that 15 % of final energy consumption must come from renewable sources. (The European Parliament and The Council 2009)

The Directive 2004/8/EC has an overall objective of encouraging the installation of cogeneration units where demand for useful heat exists. The Directive mentions examples of policy enabling such promotion in different Member States: cogeneration quotas, decrees on the sale of cogeneration electricity, laws on cogeneration. Electricity sold should be produced from high-efficiency cogeneration, as demonstrated on a guarantee of origin. Member States ought to reduce the regulatory and non-regulatory barriers to cogeneration (EC Energy 2011)

8.4.2 National policy

The following national policy documents are the most crucial in view of the research question:

- Polish Energy law (in Polish: *Ustawa Prawo energetyczne*)
- Regulations of Minister of Economy (in Polish: *Rozporządzenia Ministra Gospodarki*)

The Polish Energy Law was first drafted in 1997, but has undergone major amendments since. It is the main document regulating the energy sector in Poland (ERO 2011).
Other legislation is comprised in Regulations of Minister of Economy, published on a running basis and concerning the energy market, renewable energy, CO_2 emissions etc. (Ministry of Economy 2011)

8.4.3 Support schemes for biomass and "green electricity"

The current biomass support scheme will be presented and criticized. It will describe, among others, the green certificate scheme.

Polish *Energy law*, as mentioned in the previous section, is the most important legislative document, in which the green certificate scheme is described.

Green certificate scheme for electricity

The main rule of the scheme is that a so-called "last resort energy seller" (a selling company that is automatically assigned to a new customer in an area, unless he or she chooses differently) is obliged to buy all renewable electricity produced in the area it is responsible for (power purchase obligation), paying the generators at least the average price of electricity from previous year. In 2010 it was 197.21 PLN/MWh (approximately 50 EUR) (NREAP 2010).

A minimum percentage share of renewable electricity in the total sales of electricity to final end-users by each selling company is set by law. The minimum share of renewable electricity in 2010 was stated to be at least 10.4% and is to grow up to approximately 13% in 2020. This number is different than the expected minimum percentage share of renewable electricity in generation (17%) (NREAP 2010).

In case that in a specific year the energy selling company does not buy enough renewable electricity from producers (confirmed by green certificates issued by the Energy Regulatory Office per each MWh of "green" electricity or by substitute fee) or does not buy certificates from other companies, it has to pay a penalty fee to the Energy Regulatory Office.

There is no minimal price for a certificate; it depends on supply and demand on Polish Power Exchange. The certificates cannot be traded outside Poland (ERO 2011), (NREAP 2010).

The Polish (Ministry of Economy 2008) sets specific shares of agricultural biomass in the overall share of biomass utilised in CHPs. The Ministry states such a minimal, yearly, increasing level of agriculture – derived biomass in units between 5 – 20 MW and above 20 MW of electrical capacity. The table 8.2 shows concrete numbers that the units should comply with if they wish to receive "green certificates" for electricity.

Table 8.2 Agricultural biomass share requirements

Year	Share in units >5 MW	Share in units >20 MW (co – fired or biomass – only)
2010	25%	20%
2011	40%	20%

2012	55%	20%
2013	70%	25%
2014	85%	30%
2015	100%	40%
2016	100%	50%
2017	100%	60%

Other support measures

Other support measures are shown in the table 8.3 below:

Table 8.3 Other types of measures

Type of measure
TSO and DSOs have to give priority of transmission and distribution of electricity from renewables
RES below 5 MW and cogeneration sources below 1 MW of capacity pay 50% of the grid connection fee
Supplementary support for RES below 5 MW (e.g. exemption from some fees)
Excise tax exemption for RE (as of 2010, it was 5 EUR/MWh)
Financial support in the form of subsidies and investment loans • National and EU funds (Infrastructure and Environment and Regional programmes) • Regional funds • National Fund for Environmental Protection and Water Management

The full implementation of RE Directive into Polish law is expected with implementing necessary normative acts (NREAP 2010).

8.4.4 Forestry law

The relevant current forestry legislation will be presented, among them Forestry act, National and Regional Forest Policy and Regulations of Ministry of Environment.

The majority of forests in Poland are owned by the Polish State Treasury and managed by the State Forest's National Forest Holding.

The most important legislation act concerning Polish forests is Forestry act, implemented in 1991, with later amendments. It focuses on all forest owners, public and private, their rights and obligations. It also states which institutions are responsible for forest management, forest tax and forest planning, while the National and Regional Forest Policy is a basis for strategic decisions for public forest owners. (Sejm RP 2011) , (Lasy Miasta Łodzi 2010).

Moreover, the Regulations of Ministry of Environment concern all other aspects not mentioned in the Forestry act. Additional Polish commitment in NATURA 2000: the Member States are obligated to establish special protection areas to be included in the forestry and green sites are due to the ongoing process of expanding the NATURA 2000 network. This is also connected to two directives:

- Birds Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds

- Habitats Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and wild fauna and flora

As of 31 December 2008, the Polish Government approved 2.185 million ha of sites to be protected under the two Directives and it is to be increased to cover up to 17 % of the Poland's land mass. Additionally, the National Program for the Augmentation of Forest assumes that by 2020 the amount of forest will increase to 30% and by 2050 to 33% of the country area, which is to be done through afforestation and more sustainable forest management (The State Forests of Poland 2009b).

8.4.5 Agricultural law

The relevant current agricultural legislation will be presented, among them the regulations of Ministry of Agriculture and the Rural Development Programme.

Most of the legislation in the area of agriculture in Poland is comprised in Regulations of Minister Agriculture and Rural Development, published on a running basis and regulating agricultural markets and fishery sector (Ministry of Agriculture and Rural Development 2011).

An interesting policy document, entitled The Rural Areas Development Programme has been authored by the Agency for Restructuring and Modernisation of Agriculture. According to it, in Poland around 40% of population lives in the rural area (villages and towns up to 5 000 inhabitants), thus an increase of employment in that areas plays a crucial role. As the resources in the countryside could be used more optimally, one of the priority improvements proposed is "use of agricultural space for energy generation from RES, as well as increasing of entrepreneurship and attracting investments in rural areas", which could also mean human capital investments and better educational possibilities for village inhabitants (Łysoń 2009).

Since 2005, a financial subsidy for energy crop plantations existed, that was amended at the beginning of 2010. At first, the support consisted of initial financial subsidy from the Ministry of Agriculture, as well as yearly so – called direct – farming subsidies of approximately 200€ per hectare combined from the state and European Union. The legislation concerning EU contribution (45 € per hectare) was later annulled due to the fact that the total area of energy crops in the EU exceeded an earlier set area of 2 million hectares. Later, the state contribution was also stopped (CIRE.pl 2011),(Biznes onet.pl 2010), (ARIMR 2011), (Rolnicy.com 2011).

8.5 Implementation conditions for "New biomass" scenario

This subchapter will characterise the barriers and implementation conditions for "New biomass scenario" in three areas: technical, institutional and political. The technical implementation barriers are described in this chapter, because they form a whole with other types of barriers and are to a certain degree intertwined.

8.5.1 Technical

This section will display technical barriers that may be involved with the "New biomass" scenario.

The "New biomass" scenario has a number of conditions and barriers to implementation within technological framework.

The chapter 4 has provided a literature review, arguing that the amount of biomass possible to be produced should not cause the problem. However, this scenario is connected with increasing capacity of biomass technologies, so the most evident fact is that at the moment there is only some industry manufacturing components for biomass CHP units such as boilers, filters etc. However, there exists industry for producing coal combustion boilers in Poland, so with some alternation of technology, 100% biomass - fired boilers and other parts can be produced locally.

Another obstacle is an almost non – existent industry for energy crops cultivation and harvesting, which would have to develop significantly in order to be a source of nationally grown biomass. According to an interview with farmers of energy crops (Daszkiewicz 2007), the development of farming techniques and specialist machinery to collect willow or miscanthus on large plantations, are a must.

One of the problems in terms of market technicalities is also a lack of sufficient biomass trading opportunities among farmers and energy generators and intermediary bodies, such as stock exchanges, internet platforms etc., which could develop better availability of the biomass fuel.

It is important to notice, that if both industries start developing now, it may enable Polish manufacturing to progress significantly in the very near future, therefore reducing the technology dependency and even creating an export market, thus benefiting the trade balance.

Finally, if the forestry is to increase its wood production, new forest management techniques have also to be implemented, as well as education in that area provided to forest managers and other responsible for tree cutting.

8.5.2 Institutional

This subchapter will show institutional barriers that may be involved with the "New biomass" scenario.

Institutional barriers are relevant mainly to the areas of education, legislation and support schemes.

In terms of education, one of the crucial conditions for implementing this scenario is a sufficient number of skilled people that could design and produce the components of new biomass units, as well as relevant service personnel to provide operation and maintenance (e.g. biomass CHPs) and renewable energy planners to conduct feasibility studies and facilitate implementation. The lack of human resources is especially alarming in view of lack of vocational and technical secondary schools in Poland, the number of which decreased lately, due to great majority of students choosing general high schools instead. Certainly, it may form a barrier at the beginning, but with the state organising vocational courses for unemployed, promoting vocational secondary schools and creation of new engineering and planning courses at universities this could provide employment opportunities in the near future, as has been calculated in socio – economic analysis of this thesis. The research and innovation in the sector could be promoted through supporting international cooperation and technological clusters in Polish regions.

Legislation changes in the area of renewable energy and energy efficiency are another important matter. A better "green certificate" system is needed, as the current promotes biomass co – firing rather than a development of new highly efficient biomass technologies. For example, the level of support could be dependent on the technology age and average efficiency. Investments in energy crops could be also boosted through legally reducing the share of forest biomass in biomass CHPs, if the generators wish to receive green certificates.

Current spatial planning process in Poland may also cause a problem for extensive infrastructure investments, such as building new biomass CHPs. (Kaminski n.d.) and (Ernst and Young Polska 2007) define some of the main weaknesses of the legislation concerning spatial development in Poland. Among those, the barriers that could appear in terms of realising the "New Biomass" scenario are:

- lack of penalty for communes not drafting *Local plans of spatial development* causes them to prepare the *Decision on land development* on a running basis instead, which induces prolonged procedures for infrastructure investments as analysing each case separately takes time;
- generally lengthy process due to the lack of incorporation of the investment planning in terms of securing the access to water, electricity and gas by the communes for the areas that could be used commercially, as well as lack of sufficient coordination of different planning documents;
- lack of right for private investors to participate in the spatial management in the area, they can only issue a critique;
- lack of detail in the *Local plans* of spatial development and no reports issued by the authorities regarding methodology of decisions made in those *Local plans* and *Studies on conditions and directions of spatial development studies*, which hinders the transparency of the process.

According to (Ministry of Environment & Ministry of Economy 2011), the spatial planning legislation should be changed so that it is based on complete information and aims at unity in the planning procedures.

Moreover, the system of public – private partnership in public procurement in Poland could also enable more investments in renewable energy infrastructure. Although this system is becoming increasingly popular, environmental aspects are considered only in 10.5% of contracts, which is quite low in comparison with other EU countries. Facilitating more "green projects" should be done e.g. by increasing awareness of the officers by issuing catalogues of environmental criteria and good practice, spreading the information through websites and paper publications, as well as education campaigns (Wikipedia.pl 2011c),(Ministry of Environment & Ministry of Economy 2011).

Finally, the issue of financial support for energy crops farmers arises. It is understood that currently farmers and investors are uncertain about their future business, therefore to some extend they are unwilling to harvest willow or miscanthus. However, one may wonder if introducing a stable long – term financial support for energy crops cultivation, as is claimed by biomass producers, is a right solution, because it may make a majority of farmers choose energy crops to food crops, which may result in insufficient supply of food in the market and undesirable increase in food prices.

8.5.3 Political

This subchapter will characterize political barriers that may be involved with the "new biomass" scenario.

There appears to be a number of political obstacles for implementation of increased biomass in the Polish energy system.

For example, the Ministry of Economy may be linked too closely with the large energy companies. The partly state – owned energy companies are not always willing to innovate, as what is known is considered to be the best and the cheapest in the short term perspective and new technologies still carry some uncertainties. Furthermore, while there is no representative of RES in the Ministry, there is one for oil and gas and nuclear, the latter source not even used in Poland yet. This situation is probably caused by the fact that renewables are still treated as marginal and "immature" sources and makes it more difficult to take care of interests of RES investors.

There is a strong fossil fuel lobby in Poland and therefore newcomers and outsiders tend to be marginalized, as it is in the case of renewables developers or NGOs. Thus, a stronger political will is necessary to support the deployment of renewable energies in general, biomass among them. A solution could be for RES investors to work more in cooperation against the coal lobby, as well as to collaborate with the Energy Agencies in enhancing the knowledge on renewables in the society.

Finally, the Ministry of Agriculture should also view energy crops farming as a way of enhancing "green" jobs in the countryside, as well as diversifying farmers' production portfolio, which will increase the stability of rural areas.

8.6 Summary

The summary will reiterate the most important issues mentioned in the chapter 8, namely the theoretical structure analysis, legislation and policy relevant for solid biomass in Poland and implementation barriers for scenarios.

This chapter provided an analysis of the main actors of biomass sector in Poland and their interactions in global, macro- and microstructure. Moreover, the role of specific organisations, institutions and individuals was explained in microstructure. Additionally, legislation within the subject of the research question was described, as well as technical, institutional and political barriers for implementation.

The theoretical structure analysis identified a range of different actors, among them ministries, NGOs, biomass investors, as well as other organisations. It can be concluded that many opposing interests compete in the biomass sector, but two main hindrances to the increased biomass implementation in terms of market actors were observed: rival industries and organisations, as well as interdependencies between energy companies' shareholders.

The energy companies using forest biomass have to face paper and furniture industries, as well as NGOs that are against increased use of forest wood. However, this apparent conflict can actually be turned in favour for sustainable agricultural solid biomass producers, as the demand for their product will grow. The mutual interdependencies between the energy companies and the government, for example through vice – ministers switching positions to the executive board in coal mining companies, may prevent changing fuel to biomass, which is the second important feature of the theoretical microstructure.

Additionally, policy and legislation concerning biomass usage in the energy sector was presented in order to understand what influences the current use of biomass in the Polish energy system. Out of the EU legislation, the Directive on the promotion of the use of energy from renewable sources and the Directive on the promotion of cogeneration based on a useful heat demand in the internal energy market were identified as most important. Regarding national Polish law, the Energy law and Regulations of Minister of Economy are considered the most crucial.

Furthermore, specific support schemes concerning renewables were presented, such as renewable power purchase obligation, green certificates scheme and limited renewable heat purchase obligation. Legislation relating to the energy crops is limited to the support system that existed until 2010.

The most important legislation act concerning Polish forests is Forestry act, which focuses on all forest owners, public and private, their rights and obligations. It also states which institutions are responsible for forest management, forest tax and forest planning.

The implementation barriers identified include technical, institutional and political. Among the technical, the most crucial are considered to be lack of sufficient number of manufacturers of components for biomass CHPs, as well as industry for energy crops production and harvesting.

One of the institutional barriers that may hinder increased biomass utilisation is the insufficient number of vocational and technical secondary schools to train people for design and operation and maintenance service. Another issue is practically a lack of renewable energy planning courses at universities. Moreover, a better “green certificate” system is needed, as the current does not a development of new highly efficient biomass technologies. Furthermore, the current spatial planning process in Poland may also cause a problem for infrastructure investments, such as building biomass CHPs.

Regarding political barriers, the fossil fuel lobby in Poland is quite strong, so newcomers and outsiders tend to be marginalized, as it is in the case of energy crops investors or NGOs. Thus, a stronger political will is necessary to support the deployment of renewable energies in general, biomass among them. This could be achieved through creating a RES – responsible position in the Ministry of Economy, as well as better co –operation of different RES organisations and Energy Agencies.

9 Conclusions and recommendations

This chapter will reiterate the research question posed at the beginning and present solutions found. It will also provide conclusions of the analysis, as well as summarise the main barriers and recommendations for further research. A discussion on the results will be provided.

The figure 9.1 represents the theoretical approach to this chapter. Since the conclusion of the thesis aims at incorporating all the gained knowledge, the theoretical approach relevant here encompasses the components used in previous chapters. This approach allowed an interdisciplinary analysis to be undertaken in order to come up with answers to the research question, whilst considering specific problems in the biomass sector.

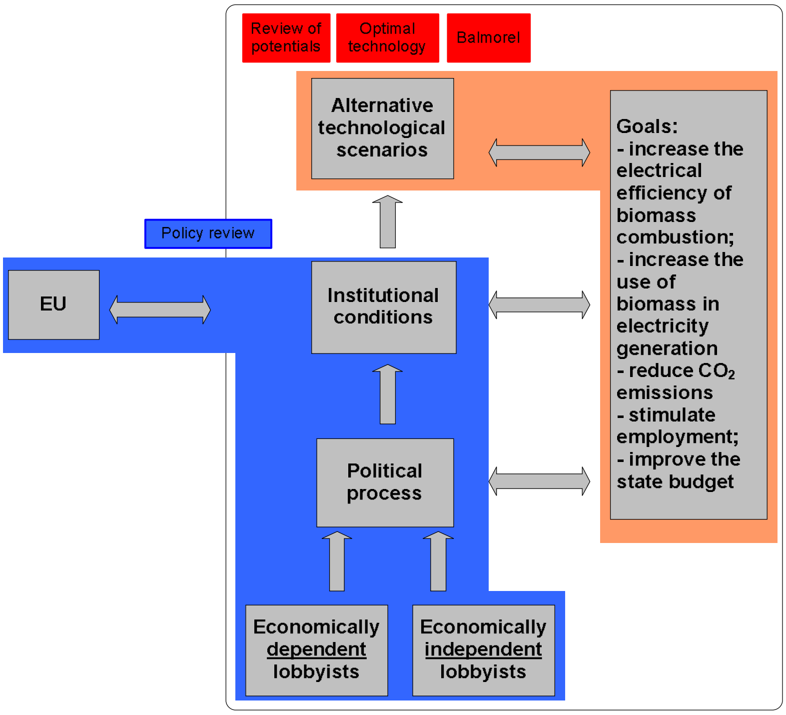


Figure 9.1 Theoretical approach to chapter 9

In the scope of the thesis, the following problems were identified and analysed in more detail:

a) Inefficient use of biomass resources in old plants
b) Underdevelopment of usage of energy crops and straw for energy purposes

Additionally, in order to analyse the aforementioned problems and find possible solutions, the following research question has been developed:

<u>How can the technical, political and institutional conditions of the biomass usage in Poland be changed in a way that solves the aforementioned problems a and b and allows greater socio - economic benefit, namely employment generation and state budget revenues?</u>

As a way of solving the problems that were mentioned above, the main research question was also accompanied by a set of more specific questions:

- What is the potential of biomass for energy purposes in Poland, given that the resources are used in efficient plants and new biomass sources are developed?
- How can biomass be used in highly efficient, new CHPs to allow CO_2 reductions and result in increasing employment levels and improving state budget in 2020?
- What are the political and institutional conditions of biomass implementation in Poland and how should they be changed to obtain a development of new resources and more efficient use of biomass?

9.1 General conclusions

This section will provide general conclusions in connection to the research question.

The research question, as well as goals identified, have touched upon a multitude of aspects and it seems that majority of the research has been successful.

The goal of increasing the electricity efficiency of biomass combustion in Polish power sector has been achieved to some extent, in two ways. First, the electricity cost calculations allowed to identify an optimal technology of wood chip – fired CHP, both efficient and cheapest, that could be further used in the system. Second, the Balmorel modelling tool, through its investment features, also identified this technology as most favourable and implemented it, according to goals set. Even though an obstacle appeared due to an impossibility of showing in a certain way the benefits of system with highly efficient plants, it is still believed simply that increased electricity efficiency allows more economic usage of fuel, therefore is a better choice.

The goal of increasing the utilisation of biomass was achieved also in two ways. Firstly, the literature review on future potentials of solid biomass in Poland demonstrates quite a significant potential available. The table 9.1 below depicts ranges of technical biomass potentials available to be tapped in the future.

Table 9.1 Summary of ranges of future biomass potential

Type of biomass	Future potential ranges (PJ)
Forest biomass	35 - 122
Forest residues and wood waste	113 - 237
Energy crops	90 - 479
Straw	26 - 130

Secondly, part of those potentials was used to model the “New biomass” scenario that increased 4 – fold the biomass share in electricity generation, allowing a number of additional benefits.

Details on conclusions regarding scenarios are shown in the section 9.2 that follows.

9.2 Scenario conclusions

9.2.1 Scenario “BAU 2020”

The first of 2020 scenarios, serving as a reference for the assessment of remaining two scenarios, showed the consequences of using in 2020 the same biomass units as in 2010 and additionally installing new plants to comply with the official objectives.

Biomass – based electricity production constituted 5.2% of the total generation, which is the smallest amount of all scenarios. The average electrical efficiency of biomass units increased by 3% in comparison to 2010, but remained the lowest out of the all scenarios. Total CO_2 emissions in "BAU 2020" scenario, compared to 2010, increased to 160.19 Mt and were the highest of all scenarios.

The investments made in this scenario will allow employing 149 989 people in the 10 – year long perspective, which is the lowest amount of all scenarios. Thanks to taxes from salaries, this scenario will allow additional contribution of 240.9 million euro to the state budget.

9.2.2 Scenario "Efficient BAU 2020"

This was the second of 2020 scenarios, showing the consequences of using in 2020 only newly installed biomass plants to comply with the official objectives.

Biomass – based electricity production constituted 5.5% of the total generation, which is larger than in the 2020 reference, but smaller than in the third scenario. The average electrical efficiency increased by 14% in comparison to "BAU 2020". The total CO_2 emissions in "Efficient BAU 2020" scenario, amounting to 157.3 Mt, dropped slightly in comparison to the reference.

However, due to some discrepancies occurring in the scenario (see chapter 6.4) it is difficult to assess the real impact of efficient units on the system, although a positive effect of increased biomass – based generation can be claimed here.

The investments made in this scenario will allow employing 191 958 people in the 10 – year long perspective, which is higher than in the reference, but lower than in "New biomass" scenario. Thanks to taxes from salaries, this scenario will allow additional contribution of 308.3 million euro to the state budget.

9.2.3 Scenario "New biomass 2020"

The third of 2020 scenarios aimed at replacing all existing biomass units with completely new in 2020 and installing additional ones, in order to analyse the influence of increased biomass usage in the Polish electricity system.

Implementing new biomass units caused a growth of 17% in biomass share in electricity production, contributing to increasing overall RES share to about 34%. The average electrical efficiency of biomass units increased by 14% in comparison to 2020 reference, but remained the same as in the previous scenario. The total CO_2 emissions in "New biomass 2020" scenario decreased to 120.16 Mt, which means a significant improvement in comparison with the "BAU 2020".

The investments made in this scenario will allow employing 739 673 people in the 10 – year long perspective, being the highest amount of all scenarios. Thanks to taxes from salaries, this scenario will allow additional contribution of 1 188 .0 million euro to the state budget, providing the largest sum.

9.2.4 Summary of scenario results

The table 9.2 below summarizes the results concerning technical and socio – economic criteria of each modelled 2020 scenario.

Table 9.2 Summary of scenario results

Criteria	BAU 2020	Efficient BAU 2020	New biomass 2020
Technical			
Generation from biomass (TWh)	10.54 (5.2%)	11.06 (5.5%)	45.02 (17%)
Average electrical efficiency of biomass combustion plants	0.33	0.47	0.47
CO_2 emissions (Mt)	160.19	157.30	120.16
Socio – economic			
Employment over a 10 year period (full time yearly employments)	149 989	191 958	739 673
Contribution to state budget [MEUR]	240.9	308.3	1 188 .0

As it is visible from the table 9.2, it is the "New biomass 2020" scenario that incorporates to the largest extent the goals of improving the electricity efficiency, as well as increasing the use of biomass in the system, allowing a solution to the two problems identified in the research question. Additionally, it allows the greatest socio – economic benefit, because it enables generating the highest number of jobs, as well as the highest revenues to the state budget.

Although the socio – economic results were based on a number of assumptions and may not fully correlate with the Polish market conditions, they do have a very crucial significance for Poland. For example, regarding unemployment especially the "new biomass scenario would help tackling the problem by decreasing it by approximately 4% each year.

In terms of state budget revenues, it is visible that the investments needed would generate a lot of income, but also the investments proposed are significant. When compared to the real state budget revenues, the amounts may not seem very realistic, but they demonstrate how the investments are able to speed – up the Polish economy.

9.3 Conclusion of implementation barriers and recommendations

The recommendations for technical, institutional and political barriers for implementing the most optimal "New biomass" scenario identified previously will be summarised.

The table 9.3 below summarizes the barriers that were identified during research and recommendations proposed.

Table 9.3 Summary of barriers and recommendations

Barriers	Recommendations
Technical	
Lack of sufficient industry for energy crops cultivation (e.g. cultivation techniques, specialist machinery for harvesting).	Mutual co – operation of agricultural universities and vocational schools with famers and relevant business to construct new machinery, promoting internships and traineeship for students.

	More state and EU funds for developing the industry itself rather than supporting only the investment costs.
Lack of sufficient industry manufacturing biomass CHP technology components (boilers, filters etc.).	Building on the experience of existing coal units production industry and developing a new biomass technology industry.
Likely requirement to import high share of biomass technologies and thus negative impact on trade balance.	Supporting the development of local industry, gradually decreasing dependence on foreign technologies through expanding Polish knowledge and skills in biomass technology.
Lack of sufficient biomass trading opportunities among farmers and energy generators and intermediary bodies.	Continuing with creating more technical conditions for trade: stock exchanges, internet platforms etc.
Institutional	
Potential lack of skilled workers in biomass sector.	Creation of new courses at universities and vocational training.
Lack of knowledge of forest managers on sustainable forest management techniques.	Education provided to forest managers and other responsible for tree cutting.
Possibly large funds needed for investments.	The beneficial socio-economic outcomes of the high investments have to be considered more often by policymakers, by investing more in innovation, business – research contacts and efficiently using the EU funds, as well as public – private partnership procurement system.
Complicated, lengthy land development and planning process before investments.	Streamlining and simplifying the process, enabling more investor participation and improving transparency. Use of the existing research on the planning legislation for identifying further barriers and developing improved legislation.
Green certificate scheme serves rather as a support for coal – companies than a motor for biomass investments.	Basing the scheme on the age, efficiency and size of the unit to support more local solutions.
Political	
Partly state-owned monopoly energy companies.	Better separation of state and fossil fuel lobby in order to create more independent energy policy.
Strong fossil fuel lobby in Poland (especially mining sector).	Improved cooperation among renewable energy developers, their trade associations and Energy Agencies. Improved cooperation among the Ministry of Agriculture and Rural Development, the Ministry of Environment and the Ministry of Economy on promotion of RES. Putting in place a RES – representative in the Ministry of Economy. Exporting coal rather than staying dependent on it for the upcoming years.
Innovation, especially in rural areas is not an important subject in political debates.	Innovation as part of political agenda, diversifying business in the countryside and attracting people with ideas and/or capital to rural areas.

In view of the research question, the technical, political and institutional conditions of the biomass usage in Poland can be changed in many ways in order to reach a number of positive effects in employment and state budget. Though all the types of barriers may become crucial hindrances, it is expected that they are not insurmountable, but need an effort of many actors, cooperating in reach a common goal of improving the use of biomass in Poland. It can be however concluded that farmers and biomass producers should for their own good, cooperate more closely together, for example by making companies together or acting within trade association, trying to oppose the strong fossil fuel in Poland and the political unwillingness to change the existing situation more than it is required by the EU.

9.4 Delimitations and research perspectives

This section will describe delimitations made and how they may have affected the results.

In the course of the thesis, a number of analyses were made and conclusions were given, although it has to be underlined that due to difficulties met, certain delimitations to the results and conclusions exist.

Due to the limited time of the thesis and its pilot project features and interdisciplinary scope, some of the aspects had to be treated more generally. The most difficulties – prone was the scenario modelling, because of the complicity of the connected energy systems and partial equilibrium characteristics of the model.

In the timeframe of the thesis, an attempt has been made to model scenarios that will allow showing the problems identified in the research question and the task was achieved in all but one scenario, where the problem of low electrical efficiency of the existing units could not be fully researched. Since the biomass – based electricity production and installed biomass unit capacities were higher than in the reference, the benefits of increasing electrical efficiency could not be as fully demonstrated as if the generation or overall biomass capacities installed were the same. However, it is logical that increasing the power that may be generated from the same amount of fuel, will cause some benefits, for example fuel savings.

Additionally, in connection with the research undertaken, conclusions and delimitations made, a number of further research perspectives were identified, that may help identifying important and interesting aspects worth examining in order to understand more the Polish biomass sector. The table 9.3 below depicts such ideas.

Table 9.4 Further research perspectives

Aspect	Reason for inclusion
Build on calculations of the generated employment and state budget by including the increase in harvesting and transport of produced biomass.	Possibly finding an even more increased socio – economic benefit of increasing biomass production and use.
Interdependencies between biomass and coal, in term of jobs losses in the mining sector and employments in the biomass sector.	The mining sector has a strong lobby and trade union representatives.
Analysis of biomass locally in a region: potentials, local barriers and system restrictions, as well as specific socio – economic benefits.	More detailed assessment on levels of biomass suitability on a regional level

Analysis on differences of using biomass in the electricity generation or heat –only boilers, as well as individual heating usage.	Does it have any influence on the optimal usage of the fuel to use it e.g. only in the district heating scheme or only in the individual boilers?
More focus on CO_2 savings and avoiding buying allowances, from the point of view e.g. industry	Large discussion among industrial producers concerning inability to afford CO_2 allowances or invest in better technologies.
Risk of losses for the trade balance by higher import share of the biomass technologies, compared with the cost of subsidies given each year to the mining sector.	Is coal really the most optimal choice for the economy?

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Appendix A Electricity and heat demand in regions and areas in 2010 and 2020

	PL_NW	PL_W	PL_Centra	PL_SE	PL_S	TOTAL (MWh)
2010	20944386	26856232	33812182	14992685	37196762	133802247
2020	28260957	36238009	45623906	20230130	50190831	180543833

	Years			Years	
Area	**2010**	**2020**	**Area**	**2010**	**2020**
Auto1_U	18813977	23136107	PL_SLAS_Gliw	1173005	1442480
Auto2_U	6109620	7513181	PL_SLAS_Kato	1848040	2272590
Auto3_U	3936689	4841063	PL_SLAS_Rybn	1164216	1431671
Auto4_U	947451	1165108	PL_SLAS_Sosn	2722712	3348201
Auto5_U	2275734	2798537	PL_SLAS_Tych	648226	797143
PL_LODZ_Lodz	2812645	3458793	PL_LUBE_Lubl	1779690	2188537
PL_LODZ_Piot	584835	719190	PL_LUBE_Pula	1263445	1553696
PL_LODZ_Sier	304599	374575	PL_PODK_Prze	1286864	1582495
PL_LODZ_Skie	281658	346363	PL_PODK_Rzes	883272	1086186
PL_MAZO_Ciec	635023	780907	PL_SWIE_Kiel	830615	1021432
PL_MAZO_Ostr	677835	833554	PL_SWIE_Sand	174378	214437
PL_MAZO_Rado	552262	679133	PL_DOLN_Jele	323523	397846
PL_MAZO_Wars	8237758	10130216	PL_DOLN_Legn	718788	883915
PL_PODL_all	1598633	1965886	PL_DOLN_Walb	288824	355175
PL_WARM_all	1923777	2365726	PL_DOLN_Wroc	1842747	2266081
PL_KUJA_Bydg	1480790	1820972	PL_LUBU_Gorz	362906	446276
PL_KUJA_Grud	1177288	1447746	PL_LUBU_Ziel	396724	487863
PL_POMO_Gdan	2319568	2852442	PL_WIEL_Kali	264546	325319
PL_POMO_Slup	878460	1080268	PL_WIEL_Koni	1021206	1255807
PL_ZACH_Szcz	1017147	1250816	PL_WIEL_Lesz	525280	645953
PL_ZACH_Kosz	919834	1131147	PL_WIEL_Pozn	3333396	4099176
PL_MALO_Krak	1587698	1952439			
PL_MALO_NwyS	492360	605470			
PL_MALO_Oswi	613521	754465			
PL_OPOL_Nysa	202222	248678			
PL_OPOL_Opol	891233	1095975			
PL_SLAS_Biel	1295513	1593131			
PL_SLAS_Byto	641468	788832			

Total (MWh)	86062000	105833000
Total (PJ)	309.8	381.0

Appendix B Prices used for modelling

The following fuel prices were used in the modelling of 2010 and 2020 scenarios (in Euro 2010)

Year	Natural gas	Coal	Lignite	Fuel oil	Light oil	Biogas
2010	6.12	3.45	1.50	6.84	12.03	6.57
2020	9.78	3.17	1.59	9.34	16.49	9.14
	Straw	**Woodchips**	**Wood waste**	**Wood pellets**	**Straw pellets**	
2010	5.78	6.12	0.60	9.29	9.29	
2020	6.62	7.08	0.60	10.44	10.44	

The following CO_2 prices were used in all modeled countries, in DKK 2009/t CO_2

2010	2020
183.04	233.11

Appendix C Detailed methodology for calculating the electricity cost from chapter 5

The following equation was used to calculate the cost of generating electricity by different technologies in the chapter 5:

Cost of electricity [€/MWh] = annual investment [€/MWh] + annual fuel costs [€/MWh] + annual O&M costs [€/MWh] - heat income [€/MWh]

In more detail, first, the data regarding investment, power and heat efficiency, fuel price, variable and fixed O&M and heat income was gathered. Next, the fuel cost was calculated as power efficiency divided by the fuel price in Euro/MWh of fuel. Next, if fixed O&M was given, it was divided by the number of full load hours to achieve it in MWh and summed up with the variable O&M in Euro/MWh. In some cases, the total O&M was already available. Then, the heat income was converted from Euro/GJ of heat to Euro/MWh of electricity by multiplying with 3.6 and multiplying by a product of division between heat and power efficiency. Next, the annual investment was calculated with 5% of rate and divided by the number of full load hours. The final cost is a result of the values mentioned in the equation above.