Evaluating the potential of renewable energy sources in Romania

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Florin Bujac

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1. Introduction

In this chapter the research background, along with an overview of Romania are presented and the research questions are formulated.

1.1. Research Background

Energy resources have always played an important role in the development of human society. Since the industrial revolution the energy has been a driving force for the modern civilization development. Technological development and consumption of energy, along with the increase of the world population are interdependent (Afgan, Bogdan and Duić, 2004).

At present, fossil fuel is still the world's predominant energy source, as it is shown in Fig.1.1., and its extraction, production and use are not considered to be efficient regardless of the new technologies available to improve its use and extraction (International Energy Outlook, 2010).

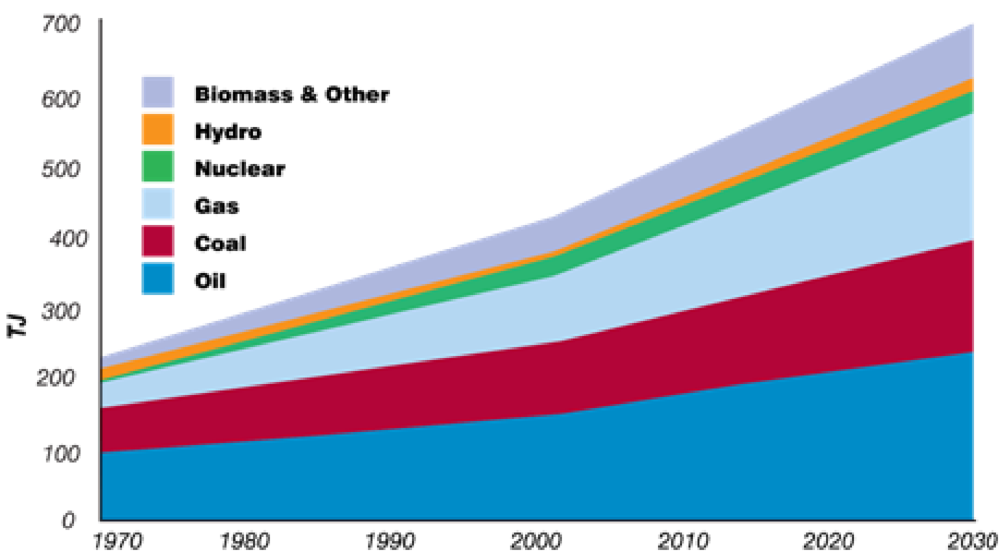

Figure 1.1. World Predominant Energy Supply
Source: (International Energy Agency, World Energy Outlook 2010)

The UNEP (United Nations Environment Program) has stated that governments need to intervene and implement alternative energy sources to achieve sustainable development and further diversify their economies. If not, fossil fuel will continue to be the world's chief energy supply which will later affect energy security and national security. Sustainable energy organizations and authors alike are aware that energy is essential as it underpins the three dimensions of sustainable development, of environment, society and economy. It has been further expressed that the main objective of a sustainable energy is its system. The energy system should provide energy service that is socially acceptable, economically viable and environmentally sound. As such, emphasis is placed on an improved energy system that is efficient throughout especially at the end use.

1.2. Facts about Romania

Romania is a unitary republic and a member of the European Union since 2007. It is situated in the south-east of Central Europe, in the northern part of the Balkan Peninsula, halfway between the Atlantic Ocean and the Ural Mountain. Romania is bordered by Hungary in the west, Serbia in the south-west, Bulgaria to the south, Ukraine in north, Moldavia in north-east and the Black Sea to the east, along 245 km of coastline. The country covers 238,391 square kilometres and is the continent's 13th largest country in area.

Romania's topography is dominated by the great arch of the Carpathian Mountains who can be divided into the Eastern Carpathians, the Southern Carpathians (or the Transylvanian Alps), and the Western Carpathians. The highest point in Romania is the peak Moldoveanu (2,544 m) in the Southern Carpathians.

The major features of relief units are: 31% mountains, 36% Sub-Carpathians, hills and plateaux and 33% plains, meadows and Danube Delta.

The climate is intermediate between temperate and continental types, with lower oceanic influences from the west, Mediterranean ones from southwest and stronger continental-excessive ones from the north-east.

The majority of the Romanian running waters have the springs in the Carpathians and their main collector is the Danube River, which crosses the country in the south on 1075 km length and flows into the Black Sea through a large delta.

The vegetation is determined by the relief and by pedo-climatic elements, being displayed in floors. Mountain areas are covered by coniferous forests (especially spruce fir), mixture forests (beech, fir-tree, spruce fir) and beech forests. Higher peaks are covered by alpine lawns and bushes of dwarf pine, juniper, bilberry etc. In the hills and plateaux, there are broad-leaved forests, prevailing beech, common oak or durmast oak. Forests cover about one-fourth of the land.

The territory of the country is devised in 41 counties, with 265 towns (of which 93 municipalities) and 2,686 communes (consisting of 13,092 villages), and Bucharest Municipality. The population of Romania, as following the last Census of population, March 2002, was of 21,698,181 inhabitants - with a density of about 91 people per square km. Bucharest is the capital city and has about 2.9 million inhabitants. (AIAE)

1.3. The Romanian Energy Potential and Targets

The type of resources and energy potential of renewable energy sources in Romania are summarized by the Romanian National Plan of Action for Renewable Energy (PNAER) in Fig.1.2.

The potential use of these sources is much smaller, because of technological limitations, economic efficiency and environmental restrictions.

The targets presented in the Romanian National Plan of Action for Renewable Energy (PNAER) for the percentage of electricity produced from renewable energy sources are the following: 35% for the year 2015 and 38% for 2020.

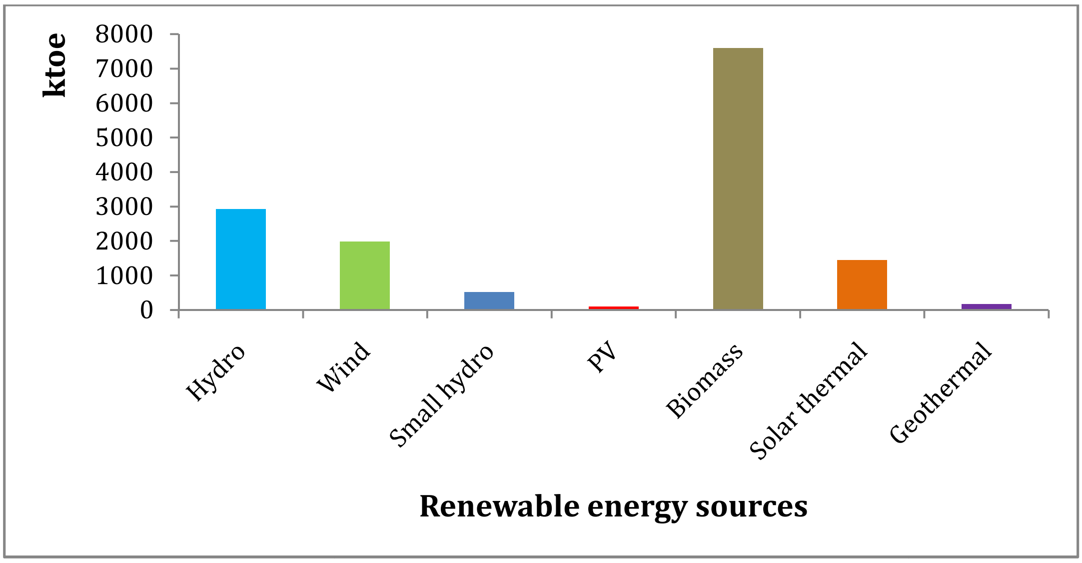

Figure 1.2. Sources and Energy Potential of RES in Romania
Source: Own creation with data from (PNAER, 2010)

Climate change is real and anthropogenic pollution is a major cause of it. One of the side effects of the industrial revolution is the increasing of fossil fuels consumption and thus burning of greenhouse gas emitting fuels. In Romania, the energy supply and its use is accountable for more than half of the green house gas emissions (Fig.1.3.), so the increasing amount of renewable energy utilization will have a major impact in the future on the amount of greenhouse gas emissions.

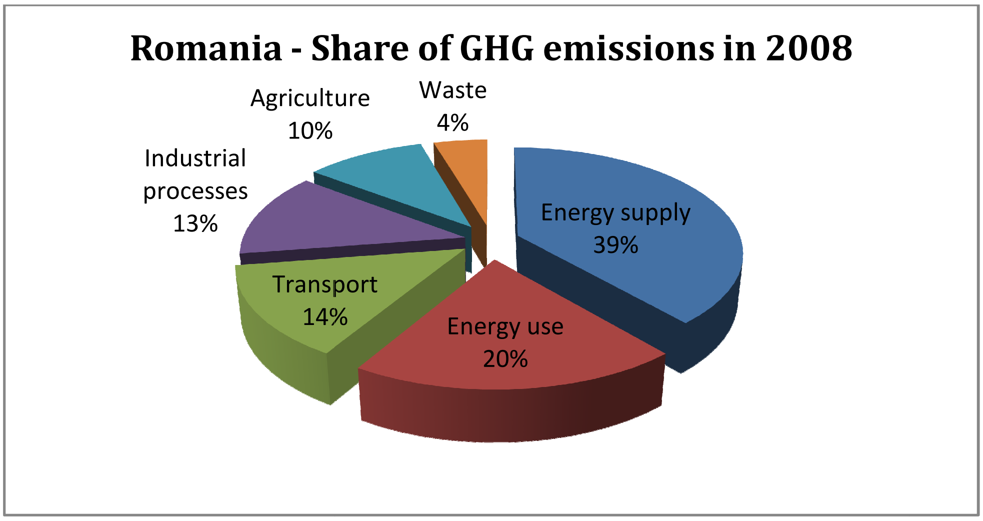

Figure 1.3. Share of Greenhouse Gas Emissions in the Year 2008
Source: own creation with data from (EEA, 2009)

1.4. Research Questions

The research questions of the report are the following:

- Which are the most appropriate sustainable solutions to be implemented and what are the consequences of their implementation?

- What are the legislative and institutional implications and the necessary changes to be implemented in the energy sector so that the sustainable solutions obtained could be achieved?

More than half of the electricity generation in Romania is produced by fossil fuels. High potentials of renewable energy sources exist but are not fully explored so it is necessary to evaluate the potential of renewable energy sources and their implementation. A study on the Romanian energy system is performed and the amount of achievable renewable energy that could be developed in the country is looked upon. A presentation of the following renewable sources: wind, biomass, solar, geothermal and micro-hydro is performed. A description and a simulation of the actual reference scenario will be carried out. An alternative scenario utilizing renewable energy sources in the share of electricity production will be analyzed and looked upon as an alternative to the actual situation in Romania. Projections for the next twenty years on the amount of renewable and non-renewable resources usage for electricity production are performed using LEAP software.

2. Methodology

This chapter seeks to explain the methodological approach that will be conducted along with the description of the methods that will be used for the project. The intention is to give the reader a picture of the plan for the study, used as a guide in collecting and analyzing data. The main purpose of this chapter is therefore to create an understanding of the different variables, which should be taken into consideration before undertaking the research. Furthermore the structure and the outline of the thesis is given in order to provide the reader with an overview of the content of the thesis.

2.1. The structure of the report

In Fig.2.1. a schematic representation of the report structure is shown. Afterwards, the thesis outline with the chapters' description is given.

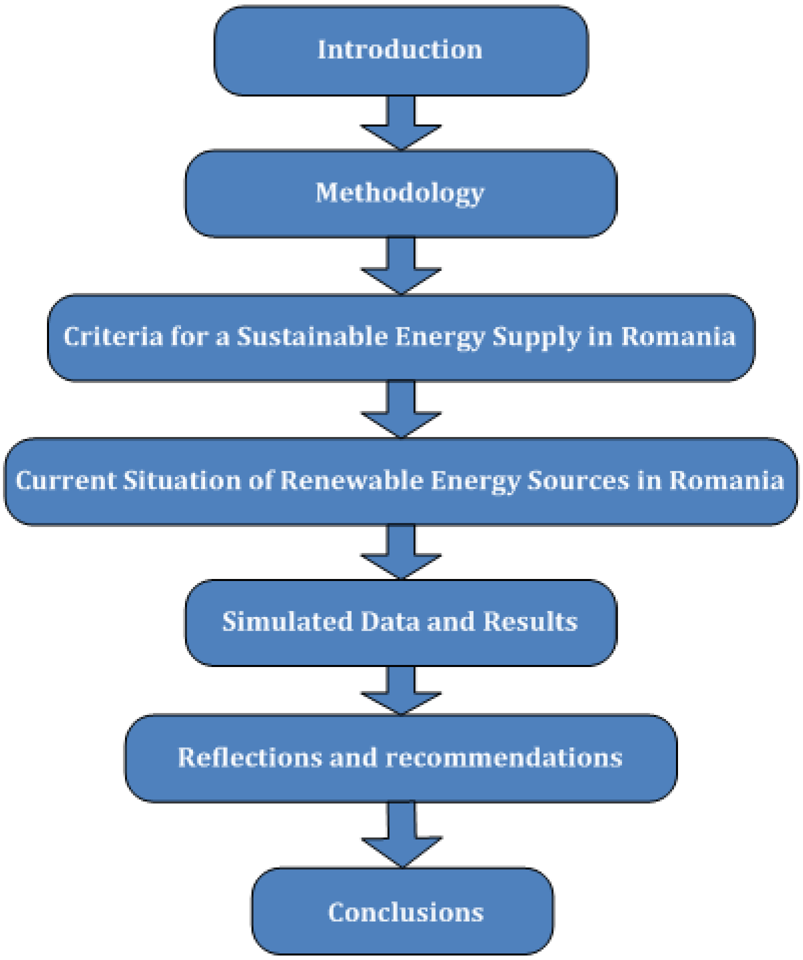

Figure 2.1.Project Structure
Source: own creation

Thesis outline

The thesis consists of seven chapters which are shortly described further on.

Chapter 1 presents the research background, facts about Romania concerning location, topography, climate and territorial division. The concept of sustainable development in Romania is also shortly presented. In the last subchapter the research questions are formulated.

Chapter 2 describes the methodological approaches and a comparison between the five planning theories is presented. The methods of conducting the research are also introduced with the aim to meet the purposes and objectives of the study.

Chapter 3 starts with a presentation of the sustainable development strategy in Romania and a description of the Romanian energy strategy. Further on a description of the stakeholders in the Romanian energy sector is performed. Next, the energy law in Europe is presented followed by its implementation in Romania, and finally the SWOT analysis of the current situation in the Romanian energy sector is undertaken.

Chapter 4 presents the Romanian renewable energy sources: wind, solar, hydro, biomass and geothermal and offers an understanding of the existing potential and circumstances of renewable energy.

Chapter 5 presents the usage of resources in electricity production in the past and in the future, until the year 2030, with the help of LEAP. Two scenarios are analysed: the reference scenario and the alternative sustainable scenario where a projection on development of renewable energy sources was implemented.

Chapter 6 is presenting an analysis of the measures recommended to be taken in Romania for an improvement into the development of renewable energy sector.

Chapter 7 describes the conclusions of the report, the limitations of the report and the implications for future research.

2.2. Planning theories

For the last 40 years planning theory was considered a source of analysis with urban and regional planning. David P. Lawrence presents in his article "Planning theories and environmental impact assessment", five planning theories that are hampering the environmental impact assessment: rationalism, pragmatism, socio-ecological idealism (SEI), political-economic mobilization (PEM) and communications and collaboration (CC). By adopting one of the planning theories mentioned above, the structuring of an ell-defined field is imposed. The term "theory" is used here because the planning theories act as an umbrella term that under which concepts, themes, and frameworks are gathered. The table below shows a brief description of the planning theories.

Rationalism	**Pragmatism**	**SEI**	**PEM**	**CC**
Strongly centralized decision making	Dispersed decision making	Weakly centralized decision making	Planning and decision making highly politicized	Open and collective decision making
Simple problems	Complex problems	Complex, interdependent problems		Moderately complex problems
Stable environmental conditions	Stable environment	Turbulent change	Interests are divergent and conflicting	
High degree of analytical capability and scientific knowledge	Limited information and resources	A consensus regarding environmental and social values	Traditional planning and market forces are clearly failing to address community needs	All relevant parties willing and able to engage in debate and discussion

Table 1. Planning Theories
Source: Own creation using ref. D.P. Lawrence (2000)

Based upon the table above, this report is adopting a ***rationalism*** believe, because a comprehensive planning is performed. Rationalism is simple, explicit, and adaptable.

The planning process adopted for the thesis is logical, consistent, and systematic. It provides a clear basis for and justification of decision making. The documentation used throughout the study is explicit and traceable.

Besides, a number of assumptions which are commonly portrayed by rationalism are present in the thesis. First, the thesis is a unitary public interest, so the goal of the thesis is widely recognized since it deals with renewable energies. The decision making is centralized because it is left up to the ideas of the writer. Third, there is a stable environmental condition, which means that the Romanian energy sector is currently something stable. With the help of LEAP a high degree of analytical capability and scientific knowledge is at last reached.

2.3. Research Method

The report starts with facts about Romania and the concept of sustainable development with its strategy. Descriptions of the Romanian energy strategy and stakeholders are presented. The energy law in Europe and its implementation in Romania are analyzed and a SWOT analysis of the current situation in the Romanian energy sector is made. Further on, the Romanian renewable energy source potential is described and the usage of resources in electricity production in the past and in the future, until the year 2030 is simulated. A scenario analysis is performed and the reference scenario and an alternative sustainable scenario are studied. A final analysis is performed at the end, and the necessary conclusions drawn. The different kinds of methods used throughout the thesis are utilised to establish the necessary knowledge needed to build the foundation for the project as well as to contribute to an accurate assessment of the different technologies.

Kumar (2005) identifies two major approaches to gathering information: secondary data and primary data.

Secondary data collection includes information, which already exists and is not gathered by the researcher. Secondary data is often represented in the form of publications like articles, reports or literature. Primary data on the other hand is so-called first hand data collected by the researchers themselves. The most common strategy is, according to Merriam (1998) a combination of both techniques. Moreover, Yin (2003) states that any finding and conclusion is likely to be convincing and accurate, when it is based on several data sources.

Considering the above, the research study will be conducted through the usage of both methods for data collection in order to increase the validity of the study.

The secondary data is any data, which has been collected and published earlier by another person and for a different purpose. This data can be used as part of the study and to provide essential background information. The secondary data consists of books and related sustainability articles and is presented in subchapter 2.3.1. The primary data consists of the usage of the software LEAP in order to develop an integrated energy environment, scenario based modelling system and is presented in subchapter 2.3.2. Also the Excel application was used for graphical representation and calculations for achieving the final results of this report.

2.3.1. Literature Studies and Document Analysis

Literature studies are used for this report as a tool to study the Romanian system and future plans of action for a sustainable development and to get knowledge on renewable energy technologies, and make feasible assumptions for future scenarios.

The main literature applied in the report is books on renewable technologies and statistical data gathered. Documents and studies from internet sources are used as supplementary literature.

2.3.2. Software tool LEAP

The software used for this thesis is LEAP meaning Long-range Energy Alternatives Planning System. The tool has been developed by the Stockholm Environment Institute in Boston, USA. LEAP can be used to track energy consumption, production, and resource extraction in all the sectors of an economy.

LEAP is an energy and environmental policy analysis tool and it can be used to create models of different energy systems, where each requires its own unique data structure. The software is a medium to long-term modelling tool and the calculations occur on an annual time-step and are designed around the concept of long-range scenario analysis, where scenarios are self-consistent storylines of how an energy system might evolve over time. With LEAP a series of alternative scenarios can be created and then can be evaluated by comparing their energy requirements, their social costs and benefits and their environmental impacts. (LEAP 2010)

3. Conditions for a Sustainable Energy Supply in Romania

This chapter starts with the description of the objectives established in the Romanian national strategy for sustainable development. Further on, the stakeholders in Romania are presented and described and the energy law in Europe and its implementation in Romania is analysed. At the end of this chapter a SWOT analysis of the Romanian energy sector is presented.

3.1. Sustainable Development Strategy in Romania

As a member state of the European Union, sustainable development is the only rational prospect for advancement as a nation, resulting in the establishment of a new development paradigm at the confluence of economic, social and environmental factors.

The European Union and its Member States have the responsibility for the implementation of the Sustainable Development Strategy by involving all institutional components at national and EU levels.

The importance of close collaboration towards the goals of sustainable development with the civil society, business, social partners, local communities and citizens is also underlined.

Four key objectives are identified:

- Environmental protection through measures that make it possible to decouple economic growth from negative environmental impacts;
- Social equity and cohesion through observance of fundamental human rights, cultural diversity, gender equality and combating discrimination of any kind;
- Economic prosperity through the promotion of knowledge, innovation and competitiveness with an aim to ensure high living standards and full and high-quality employment;
- Meeting EU's international responsibilities through the promotion of democratic institutions in the interest of peace, security, freedom and of the principles and practice of sustainable development throughout the world. (Nat. Str., 2008)

3.2. The Romanian energy strategy

The energy sector is a strategic infrastructure of the national economy on which relies the overall development of the country. The energy also represents a public utility and has an essential social impact.

The energy policy is a public utility which needs more commercial mechanisms and competitive environments. The prices should be formed in a free competition between a variety of suppliers and customers, which are progressively free to purchase their energy, as well as a transparent and stable market mechanisms surveyed by independent regulating authorities and market operators.

The basic evaluation of the energy is based on the consumption. The energy needs to sustain the development trend of the country, to improve the energy efficiency, to utilize optimum the resources and to protect the environment (Romanian Government, 2003).

The future energy strategy in Romania is presented in the document untitled The Energy Strategy of Romania for the period 2007-2020 published in the Romanian Official Gazette nr. 781 present the future energy strategy in Romania.

The overall objective of this strategy is covering the need for energy now and in the medium and long term, at a price as low as possible adequate to a modern market economy. The strategy should assure a civilised high living standard, security of supply, while respecting the principles of sustainable development. Further on the strategic objectives are presented.

Strategic Objectives

The Romanian strategic objectives presented in the National Energy Strategy Plan (2007) are divided in 3 main categories: energy safety, sustainable development and competitiveness.

1. **Energy Safety** is done by respecting the following points:

- Increase energy security by ensuring the necessary resources of energy and limit the dependency of imported energy resources
- Diversification of import sources, energy resources and transport routes
- Increased level of adequacy of the national network of electricity transmission, natural gas and oil;
- Protection of the infrastructure;

2. **Sustainable Development** by:
    - Promoting production based on renewable resources and increasing energy efficiency
    - Promoting the production of electricity and heat cogeneration plant, especially in highly efficient cogeneration plants;
    - Supporting research and development for applicable projects
    - Reduce the negative impact of energy on the environment and efficient use of primary energy resources.
3. **Competitiveness** means:
    - development of competitive markets for electricity, natural gas, oil, uranium, green certificates, emissions trading of greenhouse gas and energy services
    - liberalization of energy transit
    - continue the restructuring and privatization in the electricity heating and natural gas sectors
    - continuing the process of coal sector restructuring

3.3. Stakeholders in the Romanian Energy Sector

According to (Miron and Preda, 2009) the structure of the stakeholders in the Romanian energy sector is categorized as follows:

a. *Key stakeholders* –can have a major influence or are important to the success of a project or a program

b. *Primary stakeholders* – composed by individuals, groups of individuals or institutions who are affected either positively or negatively by a project or a program who has impact on them.

c. *Secondary stakeholders* – are different intermediary entities that can or cannot take part in the decision-making process

Also, the actors can be placed in the three spheres of society: state, civil society and the market, as shown in Fig.3.1. The color chosen for their representation is red, for the *Key stakeholders,* yellow for *Primary stakeholders* and blue for *Secondary stakeholders.*

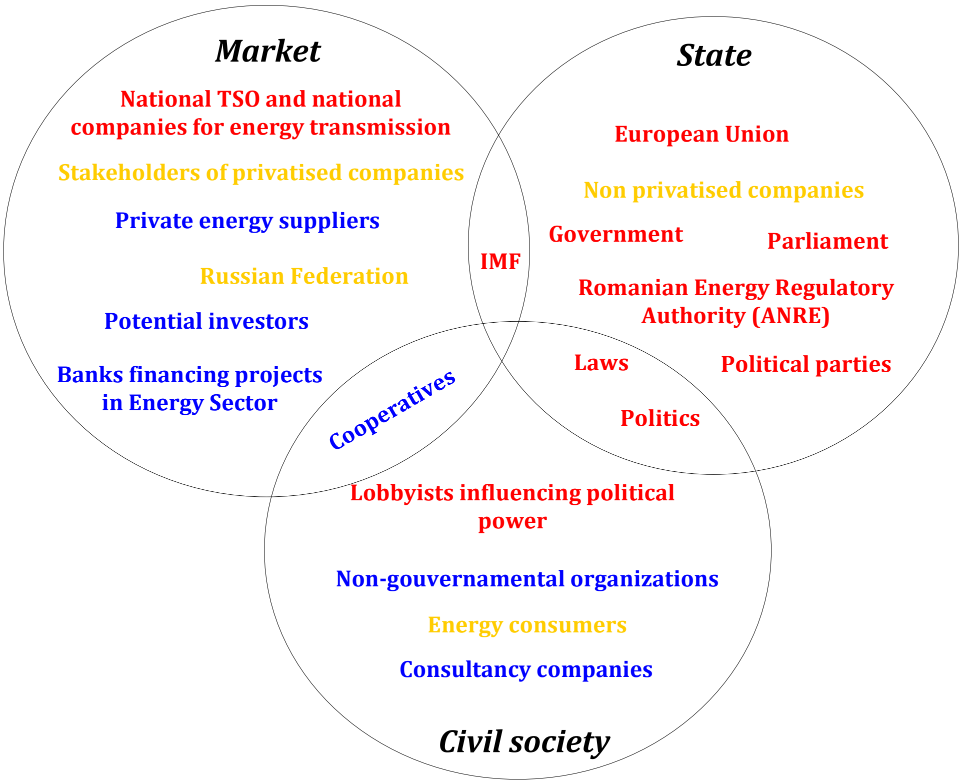

Figure 3.1. The Three Spheres of the Romanian Society and their Actors
Source: own creation

Further on a more detailed description of the categories mentioned above is presented, following the structure by Miron and Preda (2009):

a. *Key Stakeholders*, colored in red in Fig.3.1., are the following:

- The European Union, represented by its institutional architecture; the important objectives that have to be accomplished for the EU energy strategies are: the security of supply, competitiveness and sustainable development. The European directives are adopted at national level through laws or government decisions.

- The Romanian public authorities as The Romanian Energy Regulatory Authority (ANRE). The government, the public authority of the executive role must have interests in protecting the national economic and social interests, to respect the European Union directives and to implement the EU policies.
- The national companies for energy transmission and system operators. These are: Transelectrica S.A. who is responsible for transportation and dispatch of electricity through the national grid, Electrica S.A. (electricity distribution and supply), Termoelectrica S.A. who manages heat and electricity generation, Romgaz the largest national gas producer and Transgaz, the national gas transmission company);
- Lobbyists that are influencing the political power related to the decisions in the energy sector
- Political parties
- International Financial Institutions as International Monetary Found is a key stakeholders.

b. *Primary Stakeholders,* the ones colored in yellow in Fig.3.1 are the following:

- Non privatised companies are the state companies in the system: resources extraction companies for coal, oil and natural gas, producers, distribution companies, supply companies.
- Shareholders of the privatised companies
- The energy consumers (electricity, natural gas, coal, etc.)
- The Russian Federation regarding the source of the natural gas necessary to be imported by Romania

c. *Secondary Stakeholders,* colored blue are*:*

- Potential investors – the investors that are interested on the Romanian energy market;
- Private Romanian energy suppliers
- Banks financing projects in energy sector;
- Consultancy companies
- Employees and trading unions of the companies in the sector
- Non-governmental organizations

It can be observed in Fig.3.1 that the majority of the key stakeholders who can have important influence on the development of the energy projects or programs are present in the *State* circle. This fact shows that a good functioning of the State and its related institutions and aspects will help and encourage a proper and beneficial evolvement of the energy related projects. Further on a description of the Energy law in Europe and its implementation in Romania is described.

3.1. Energy law in Europe and its implementation in Romania

The energy policy for a competitive Europe is broadly presented including the Third Energy Package and The Climate Change Package. Further on, the implementation of these two EU packages in Romania is emphasized.

3.1.1. Energy policy for a competitive Europe

Europe's energy policy law is securing the supply of energy at affordable price levels in order to maintain decent living standards. For reducing the negative effects of energy use, predominantly fossil fuels, on the environment, the EU policy focuses on creating a competitive internal energy market. This energy market is offering quality service at low prices and with lower consumption of energy; it reduces the dependency on the imported fuels and is developing the renewable energy sources. (EC.E. 1)

Third Energy Package

The Third Energy Package measures adopted by the Commission will certify the fact that all European citizens can take advantage of the numerous benefits provided by a truly competitive energy market. The focus of this legislative package is on the consumer choice, cleaner energy, security of supply and fairer prices. The measures that the Commission is proposing are the separation of production and supply from transmission networks, cross-border trade in energy, more effective national regulators. Also other proposals are the cross-border collaboration and investment, greater market transparency on network operation and supply and a higher solidarity among the EU countries (EC.E. 2).

Climate change package

Through this package measures for combating climate change and promote renewable energy are established. The Climate Change Package is intended to achieve the EU's overall environmental target of a reduction in greenhouse gases and a 20 % share of renewable energy in the EU's total energy consumption by 2020.

It also refers to achieving a 10% share of energy from RES in the transport energy consumption of each member state. The Emissions Trading System for greenhouse gases is revised in order to reduce emission in the energy-intensive sectors, starting the year 2013. The cutting of greenhouse gas emissions should be at 20% compared to 1990 levels by the year 2020.

Also a decision for reducing green house gas emissions in other activities (e.g. transport, agriculture and housing) sets binding emissions targets for EU member states in sectors not subject to the EU's Emissions Trading System. New standards for carbon dioxide emissions for new passenger cars will be applied from the year 2012 and regarding biofuel, the blending biofuels into petrol and diesel is facilitated.

For climate change mitigation, a regulatory framework regarding carbon capture and storage (CCS) technology deployment is also adopted (EC.C.).

3.1.2. Implementing EU law packages in Romania

The Climate change Package and Third energy package will result in structural changes in the economy of European Union, as industrial areas tend to be concentrated more in western countries because of the availability of advance technology investments. Also an effect will be on the categories of workers that will migrate from the eastern to western part of Europe.

Further on the description of what challenges will the two packages (Third Energy Package and The Climate Change Package) bring for Romania. (M.Constantin, 2010)

Third Energy Package

This package is expected to have an impact on the elimination of the main irregularities of the Romanian energy market, for example the maintenance of regulated prices for non-household consumers, often big industrial consumers.

Romania is implementing some of the requirements of the Third Energy Package like the independence of the National Regulatory Authority (ANRE) or the unbundling regime.

The effects that the Third Energy Package will have on Romania will include stricter market monitoring and border opening for interconnection capacities. (M.Constantin, 2010)

- *Unbundling*

Additional unbundling requirements for the transmission system operators are needed according to The New Electricity Directive. The three options given by the Member States are the following: full ownership price separation, independent system operator model; or independent transmission operator model. Romania has a single Transmission System Operator (TSO) at the moment named Transelectrica S.A. The transmission and system services were separated completely form the generation, distribution and supply activities, but technically the electric power system remained unitary managed by Transelectrica.

Transelectrica does not have ownership rights over the grid because according to the Romanian law the transmission grid should always remain in the public ownership of the State. In 2006 Transelectrica was listed in the Bucharest stock exchange, and the state owns 75% of the shares in Transelectrica. It can be considered that the Romanian TSO has unbundled legally, functionally and regarding ownership, corresponding to the requirements of the New Electricity Directive.

Regarding distribution system operators the new directive does not require strict unbundling of vertically integrated distribution system operators, thus the level of concern is not the same as in TSO's case.

The Romanian Law no.13/2007 replicates the provisions of the New Electricity Directive in terms of unbundling the distribution system operators. As the New Electricity Directive requires that the vertically integrated distribution systems should not cerate confusion concerning the separate identity of the supply branch, the distribution system operators might have to change their market appearance. (M.Constantin, 2010)

- *Impact of the Third Energy Package on the Romanian National Regulatory Authority (ANRE)*

The third energy package has requirements that are referring to the strengthening and reorganising the independence of the National Regulatory Authority (ANRE). In general ANRE is respecting these requirements by being the single national regulatory authority and by being competent in the electricity and gas markets.

Regarding independency ANRE is an autonomous public institution, financed by its own revenues. Respecting the Third Energy Package, the top management is appointed for a 5 years mandate and formally the decisions are made independently from political bodies of private entities. The top management of ANRE is appointed and dismissed by the Prime Minister (M.Constantin, 2010).

In Janurary 2009, the Romanian Prime minister appointed Petru Lificiu, a member of the democrat liberal party, to be the president of ANRE (Mediafax, 2009). The European commission threatened Romania with sanctions because of the politically engaged members and lack of specialists in energy authority. As a result the president of ANRE Petru Lificiu, was replaced by Iulius-Dan Plaveti in July 2010. Iulius-Dan Plaveti is a person with experience in the auto import business and is supported by Cristache Radulescu, a member and a very influential figure inside the democrat liberal party. After being replaced from the position of president of ANRE, a position of vice-president was offered to Petru Lificiu. His permanent removal from an executive position was avoided because it would have created more problems for the government members. Through Lificiu's intervention, the government members were keeping the gas and energy prices unchanged even with the risk of financial loss for distributors because of electoral and social considerations (Financiarul, 2010).

As presented, the National Regulatory Authority (ANRE), self described as a 'public independent body of national interest', appears to be politically influenced fact that could have an impact on the decision making inside it.

- *Customer protection*

Customer protection is one of the main focus of the Third Energy Package and the new requirements include free of charge procedures of supplier change, consumption data transparency and protection to vulnerable consumers.

Romania has, in theory a fully liberalised market, but in reality the degree of de-regulation is 50%. In June 2009 the European Commission complained about the domestic market for gas and electricity and the fact that ANRE still regulates the prices for non-households consumers. A draft regulation, concerning the rights of the consumers to change their electricity supply, was submitted to public debate and it represents a step forward for a more efficient procedure (M.Constantin, 2010).

Climate change package

- New EU Emissions Trading Scheme (ETS) Directive

Under the commitments of the Kyoto protocol, in order to minimise the economic costs of combating climate change, EU countries have agreed to establish an internal market in order to trade CO2 pollution permits. Under the ETS scheme approximately 10.000 energy-intensive plants, which belong to the power generation, iron & steel, glass, cement, pottery and bricks industries, are included. As a result, these energy-intensive plants across EU are able to buy and sell permits to emit CO2, representing 40% of the total CO2 emissions in the EU. Companies that exceed their quotas are allowed to buy unused credits from those that are better at cutting their emissions. These quotas that are defined through a national allocation plan for each individual plant are submitted by member states and approved by the Commission. In this way the Commission will stimulate innovation and create incentives for companies to reduce their carbon emissions (EurActiv, 2009).

With almost half of the electricity consumption being generated from fossil fuel and with a contemplated increase in greenhouse gas emissions in the near future in the context of economic growth, Romania is one of the Member States that will be most affected by Climate Change Packages.

- *Renewable energy directive*

In 2004 Romania implemented a quota system with green certificates (GC) that can be traded. Purchase Obligation for supplier companies and the obligation to fulfil an annual quota of purchased RES electricity.

The green certificates are issued to electricity production from wind, solar, biomass or hydro power generated in plants that have a capacity less than 10 MW.

In Fig.3.2., the quota obligations from the year 2005 until 2020 are presented. (EREC)

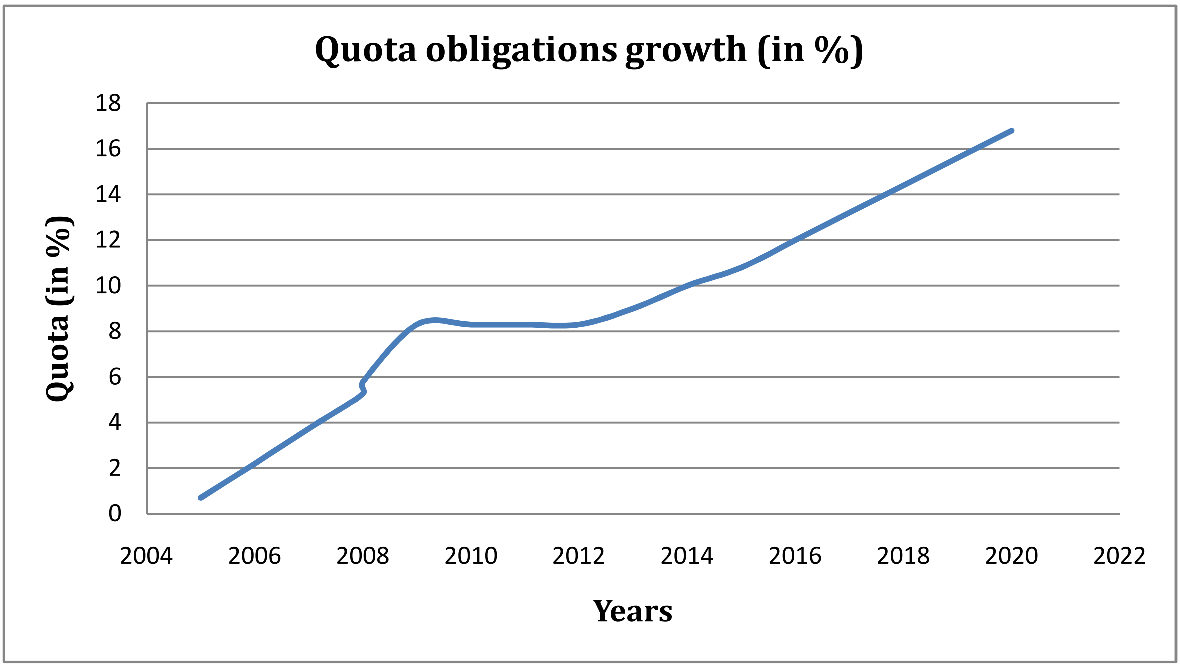

Figure 3.2.Quota Obligations for RES from 2005 to 2020
Source: (EREC) and ENERO

The new Law 220 issued in November 2008 gives important improvement of the market incentives for renewable energy sources, such as:

- One green certificate for every 1 MWh delivered in the electricity grid by the generators of hydroelectricity from new hydro power plant (HPP) or HPP with max. 10 MW installed power and rehabilitated;
- One green certificate for every 2 MWh delivered in the electricity grid by the generators of hydroelectricity from HPP (installed power 1- 10 MW) (not corresponding to the conditions as stated in the previous point)
- Two green certificates for each 1 MWh delivered in the electricity grid by the generators of hydroelectricity from HPP with max. 1 MW/unit installed power
- Two green certificates for each 1 MWh delivered in the electricity grid by generators from wind-until 2015; 1 green certificate -starting from 2016
- Three green certificates for each 1 MWh delivered in the electricity grid by generators from biomass, biogas, bio liquid, gas of waste fermentation and geothermal energy

- Four green certificates for each 1 MWh delivered in the electricity grid by generators from solar sources (EREC).

The range in which the green certificates can be traded is 27 to 55 euros each (EREC).

The benefits of law no. 220/2008 have been appreciated. Due to missing comprehensive application norms that should been issued by ANRE and due to numerous rumours regarding possible amendments resulting in a reduction of green certificates, the incentives scheme is no longer perceived as a stable and predictable instrument.

Also a requirement of the Renewable Energy Directive is the obligation on Member States to ensure priority access or guaranteed access to the grid for electricity produced from RES. Transparent and non-discriminatory rules regarding cost of grid connection and reinforcement and a reasonable and precise timetable for receiving and processing requests for grid connection are required. Law 220/2008 provides for priority access for renewable energy to the transmission and distribution grid. The grid operators have to make a detailed estimation of the costs that are associated with the new generators of renewable energy wishing to connect to their network. Unfortunately no such norms were prepared until now, and with no control of ANRE over the norms the requirements over the Renewable Energy Directive are not satisfied. Therefore amendments to law 220/2008 are necessary.

Romania introduced Guarantees of Origin in 2005 and the current system complies with the Renewable Energy Directive. An energy labelling system is also implemented but this system does not use the information contained in the Guarantees of Origin. Guarantees of Origin are used for the moment just for statistical purposes and for determining the degree of achievement of the national energy targets (M.Constantin, 2010).

- *The Carbon Capture and Storage (CCS) Directive*

Governmental support is essential in order to access incentives from EU regarding CCS projects and additional funding is also necessary. The government announced the first project for CCS and is currently in pre-feasibility phase of preparation (M.Constantin, 2010).

3.2. SWOT Analysis of Current Situation in the Romanian Energy Sector

Taking as a reference the National Energy Strategy Plan (2007) the SWOT analysis of the current situation in the Romanian energy sector is presented as follows:

STRENGHTS – competitive advantages

- Long tradition in the energy industry and national energy resources especially coal, and oil and gas reserves
- Complex and diversified infrastructure: national network for transporting electricity, natural gas, crude oil, petroleum. Refining capacity and important capacity of transport on the Black Sea
- Diversified and balanced structure of electricity production
- Ongoing nuclear energy program, positively perceived by public opinion, based on safe technology, recognized worldwide
- Technical expertise and skilled human resources for activities in the energy sector
- Moderate potential for exploiting the renewable resources
- No difficulties in respecting the commitments under the Kyoto Protocol
- Relative high capacity to interconnect the electricity transmission and natural gas with neighboring countries with similar systems;
- Potential of coal resources with a high degree of knowledge;
- Energy potential of coal resources put in value by seven underground mines;
- Quality of transport infrastructure, electricity dispatch;
- The operator of the wholesale electricity market is an experienced operator capable of becoming an operator of the regional market;
- Total liberalization of electricity markets and natural gas.

WEAKNESSES – system deficiencies

- A number of production, transportation and energy distribution facilities are partly obsolete having an outdated technology, with high consumption and operating costs;

- Outworn installations and equipments used for the mining of lignite, having operating costs and low performance
- Lack of equipment for the implementation of advanced technologies in the sector of coal extraction;
- A growing dependence on imports of natural gas, as for now there is only one source;
- The duration of functioning exceeded for 69% for natural gas transportation pipelines and for about 27% for measuring and regulating stations;
- Low levels of financing sources in comparison with the investment needs of the infrastructure for National Transportation System of natural gas (NTS);
- Inhomogeneous structure in terms of the pressure and diameter of the NTS, which leads to big problems when insuring the pressures towards the system extremities;
- Reduced energy efficiency of the production-transportation-distribution- final energy consumer- chain
- Lack of financial measures to support projects and programs concerning the growth of the energy efficiency and to the use of renewable energy;
- Organization of the electricity generation sector on single-technological pathways;
- Low performance potential of state owned companies within the mining and energy sector;
- Existence of price distortions to the final consumers;
- Reduced research ,development and dissemination capacity of the mining and energy sector
- Major financial efforts to comply with environmental regulations and the decommissioning of nuclear and thermal power units, released land greening installation, and final disposal of the used nuclear fuel and radioactive waste;
- Most electricity production units do not comply with the EU regulative emission norms for certain pollutants. The alignment to these norms requires significant funding and its achievement is realized gradually;
- Incoherent policies for highlighting new perimeters for lignite mining;
- Relatively long period of time for the development of new coal and uranium production units

OPPORTUNITIES

- Favorable geographical position for developing pan-European pipes for oil and natural gas projects;
- The existence of physical energy markets, as well as access to regional electricity and natural gas markets with the opportunity to achieve system-level services
- Available capacity of national gas transmission system that can ensure user requests acquisition;
- Attractive investment climate for both foreign and domestic investors, including the privatization of various companies that are currently in state ownership;
- Increased confidence in the Romanian capital market, which allows a successful listing on the Stock Market of energy companies.
- Increased investment opportunities in the field of energy efficiency and unused renewable energy resources;
- Access to the EU structural funds projects in the field of energy efficiency;
- The existence of a major hydropower sector, which is able to provide the necessary volume of system technology services;
- The existence of a long term experience in mining and of an important infrastructure for exploiting the domestic primary energy resources of coal and uranium;
- The existence of new perimeters with considerable reserves of lignite.

THREATS - Risks and vulnerabilities

- Economically exploitable reserves of oil, natural gas and uranium, provided that no major new deposits will be discovered;
- The volatility of oil prices on international markets;
- The trend of climate change characteristics and instability of hydrological regime;
- Possible negative effects on the competition in the European energy sector, due to the concentration of power industry trends;
- A high growth rate in energy demand in the context of economic recovery;
- Significant share of the population who has a high degree of vulnerability towards the average European energy prices;

- Lack of effective fiscal instruments for supporting investment programs in energy efficiency, cogeneration development based on the available heat demand, usage of renewable energy sources for the production and development of thermal energy;
- Possible blocking of coal mining activity due to the accumulation of debt
- Possible blocking of lignite mining activities due to lack of regulations
- Selection, retention and motivation of human capital, which is necessary for the implementation of strategies and safe operations of the national energy system;
- High mining costs of uranium due to the variation of mineralization parameters and its discontinuity;
- Opposition of local authorities towards the opening of new production facilities in the exploitation of uranium;
- The possible sharp increase in world price of uranium;
- Possible change in public attitudes towards the construction of new nuclear power plants and radioactive waste storage sites;
- Difficulties in providing technology system services during dry periods;
- Additional costs arising from the application of the Directive on establishing an emissions trading scheme for greenhouse gas emissions;

4. Current Situation of Renewable Energy Sources in Romania

This chapter gives an overview of the different renewable energy sources (wind, solar, hydro, biomass and geothermal) which are present in Romania and the conditions under these develop.

4.1. Renewable Energy Sources (RES) - overview of Romania

Due to its marine climate, southern location and diverse geography, Romania has an extremely extensive renewable energy sources potential.

Through law 139/2010, the renewable energy sources are defined as: *"Non-fossil energy sources, namely: wind, solar, geothermal, hydrothermal and ocean energy, hydro, biomass, landfill gas, known as gas storage and gas from sludge digestion sewage treatment plants and biogas".*

The combination of political commitment and decision making as well as support mechanisms that are now set in the Romanian energy laws. These laws are the key to a successful development of renewable energies in Romania.

The Energy laws promoting production of renewable energy have set well defined targets for all types of renewable energy production.

RES project implementation will reduce the dependency on the imported energy and will improve the balance of payments for the energy sector. (Inv.E. 2010)

In Figure 4.1. the map of renewable energy potential of Romania is shown.

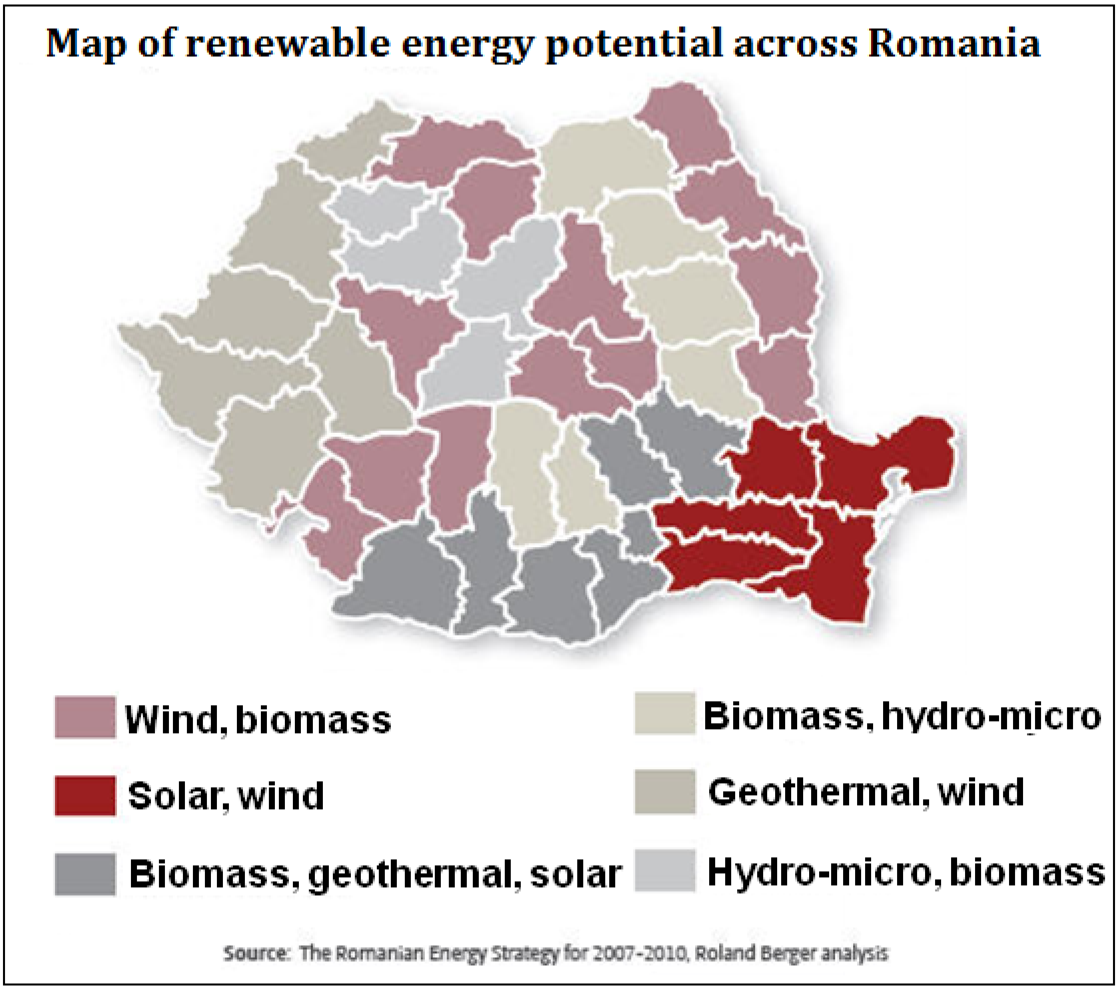

Figure 4.1.Map of Romania with the Renewable Energy Sources Potential
Source: adjusted from (Roland Berger)

4.1.1. Wind Energy

Romania's potential in wind energy is considered to be the highest in South Eastern Europe. The Moldova and Dobrogea provinces (in the southeast of the country, near the Black Sea) were considered the most appropriate areas for wind farm developments. The southeast of Dobrogea was ranked second in terms of potential in Europe according to specialized studies.

In July 2010, the Romanian Energy laws 220/2008 and 139/2010 have been signed by Parliament and the President. These laws offer support to large scale commercial development of Wind energy solutions over the next 7 years. Europe's leading energy utility companies will develop large scale wind energy investments in Romania.

Among the biggest companies is the Czech Energy company called CEZ whose wind park is the world's largest outside the USA. This shows that wind energy segment is becoming more developed (Inv.E. 2010).

The fact that Romania has large areas onshore with low population provides optimal condition for wind energy development.

Wind potential in Romania is mainly concentrated in the Dobrogea, Moldova and Banat regions. It is estimated at around 14,000 MW installed capacity, generating around 23 TWh per year. Wind resources in Romania have been thoroughly analyzed over the last couple of years, revealing high potential in the practical set-up of both small independent units for rural areas and large off-shore projects. According to an Erste Bank report, Dobrogea – and most notably Constanta and Tulcea – establish Romania as the second best location for developing wind farms in Europe and the leading one in the region (Roland Berger).

The Figure 4.2 gives an overview of the wind energy potential in Romania, measured at 80 meters.

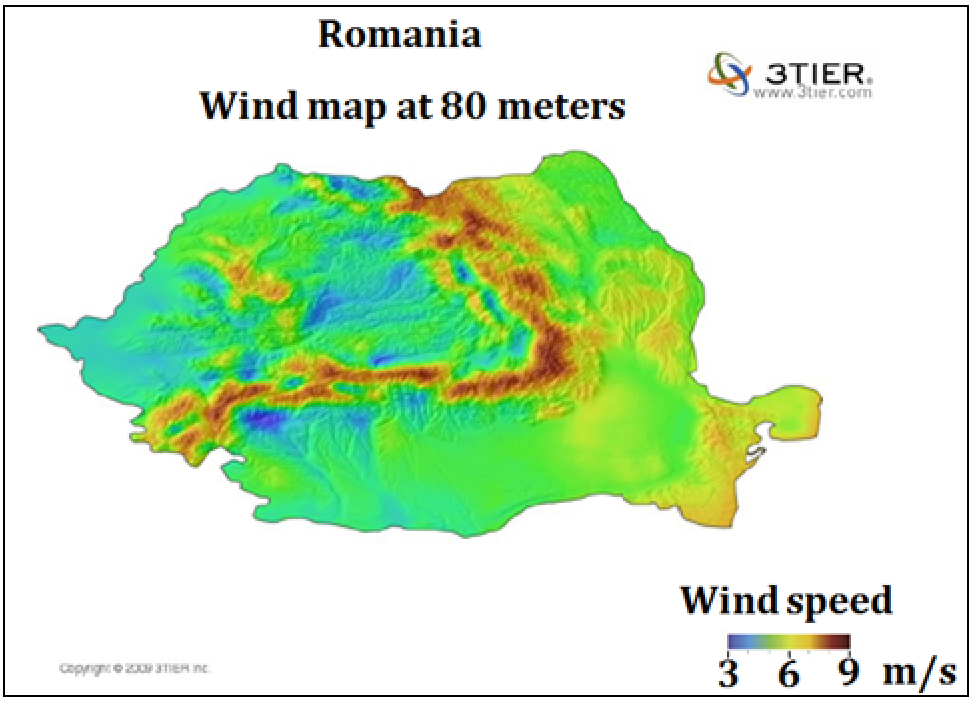

Figure 4.2. Wind Energy Potential in Romania
Source: adjusted from (EBRD)

4.1.2. Solar Energy

Solar energy shows a moderate potential throughout the entire territory of the country, but the most abundant solar resources are located in the southern part of the country and Dobrogea. Considering solely the solar electricity potential, its potential is approximately 1.2 TWh. (Roland Berger). A further description of Photovoltaic (PV) solar installations and some general advantages and disadvantages can be found in Appendix 1.

A more detailed picture showing the Romanian map with the yearly sum of global irradiation (kWh/m2) is shown in Fig. 4.3.

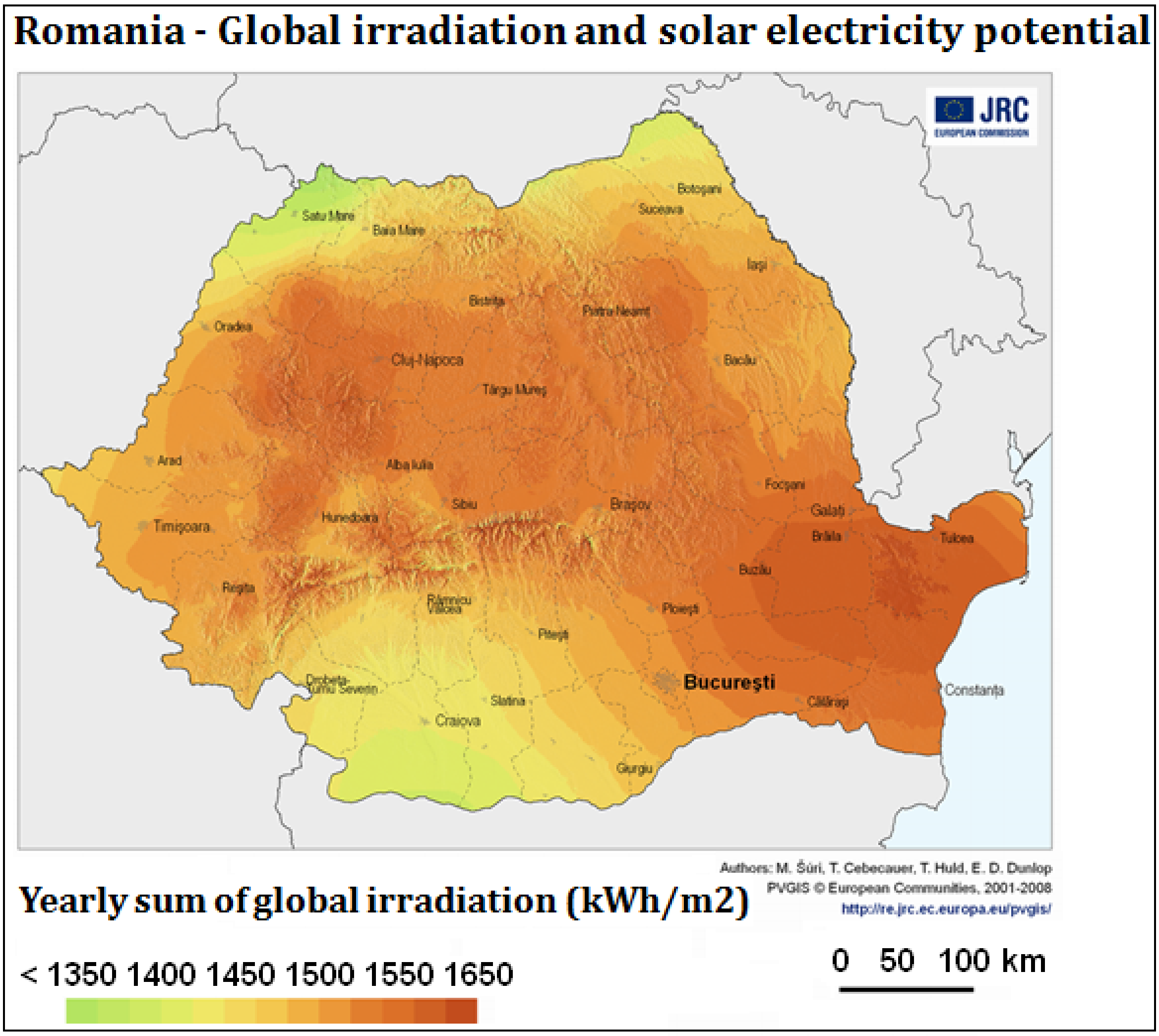

Figure 4.3. Solar Energy in Romania
Source: adjusted from (E.C. JRC) European Commission Joint Research Centre

4.1.3. Small Hydro Power (SHP)

The analysis of the total small hydro potential in Romania reveals the possibility to install around 780 small hydroelectric plants (of below 10 MW/unit), with a total power of 2,150 MW, able to provide approximately 6 TWh per year.

At the moment, small hydro plants in Romania account for a total capacity of 1,125 MW, but this capacity is not entirely functional, leaving the high potential of small-scale hydropower somewhat untapped. (Roland Berger)

The most promising applications and priorities are presented below:

Promising is the fact that it has been estimated that there are more than 2000 locations in Transylvania, in the mountains that are suited for the development of small hydro plants, and from an economic perspective the developments offer greater economic returns than obtainable from renovating existing facilities. (Inv.E. 2010)

4.1.4. Biomass

Biomass is defined as stored energy of the sun in form of organic matter, which is available on a renewable basis. Wood and wood wastes of forests, fast-growing trees and plants, mill residues, agricultural crops and wastes, livestock residues as well as aquatic plants are considered as biomass. It is regarded as an energy source that is relatively cheap, easy to transport and to store as well as a resource with few environmental concerns [Mukhopadhyay (2007: 105)]. A brief description of the biomass applications is presented in Appendix 2.

In Romania, the majority in the biomass potential is cereal, corn and grapevine waste, followed by firewood, biogas, urban household waste and wood waste as presented in Fig.4.4.

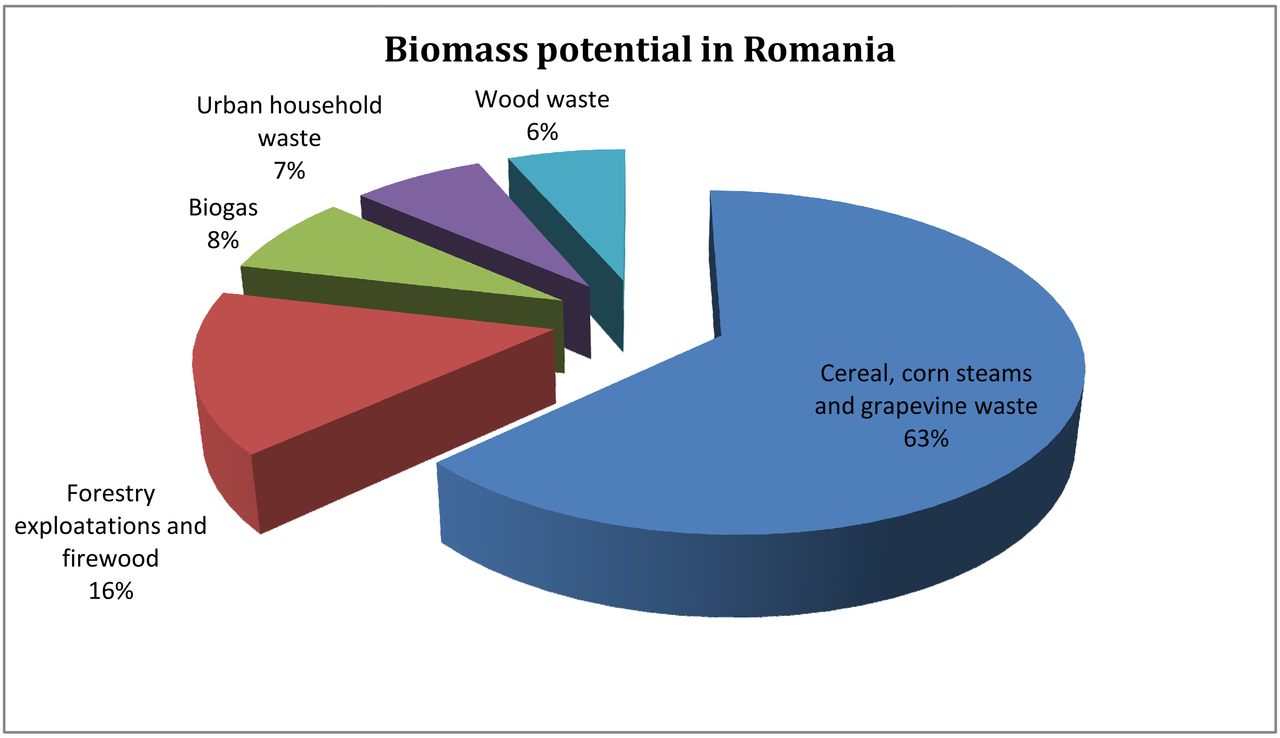

Figure 4.4. Biomass Potential in Romania
Source: own creation with data from: I.Iancu, F.Racasanu, M.M. Voronca (2004)

A further description on biomass applications is presented in the Appendix.

Biomass carries the highest potential for green energy production in the country, amounting around 88.33 TWh per year. It is estimated that approx. 36% of this potential is currently used, but so far, biomass usage has mainly focused on household firewood: direct burning, space heating, cooking and water heating account for around 95% of the current biomass exploitation, while industrial biomass use equals only 5%. Carpathians and Sub-Carpathians provide around 66% of the firewood and wood waste, whilst the South Plain, West Plain and Moldova regions provide approximately 58% of the agricultural waste. About 27% of Romania's land is covered by forests, whose exploitable potential is estimated at 20,000 cm. (Roland Berger)

4.1.5. Geothermal Energy

This subchapter is focusing on the geothermal potential of Romania. More information about geothermal power generation can be found in the Appendix 3.

Regarding geothermal energy, Romania shows the third highest potential in Europe, with major potential locations in the Western Plain, South Plains (Bucharest region) and Southern Carpathian regions. Total potential reaches around 1.94 TWh per year (Roland Berger). Fig. 4.5. shows the availability of geothermal energy potential in Romania.

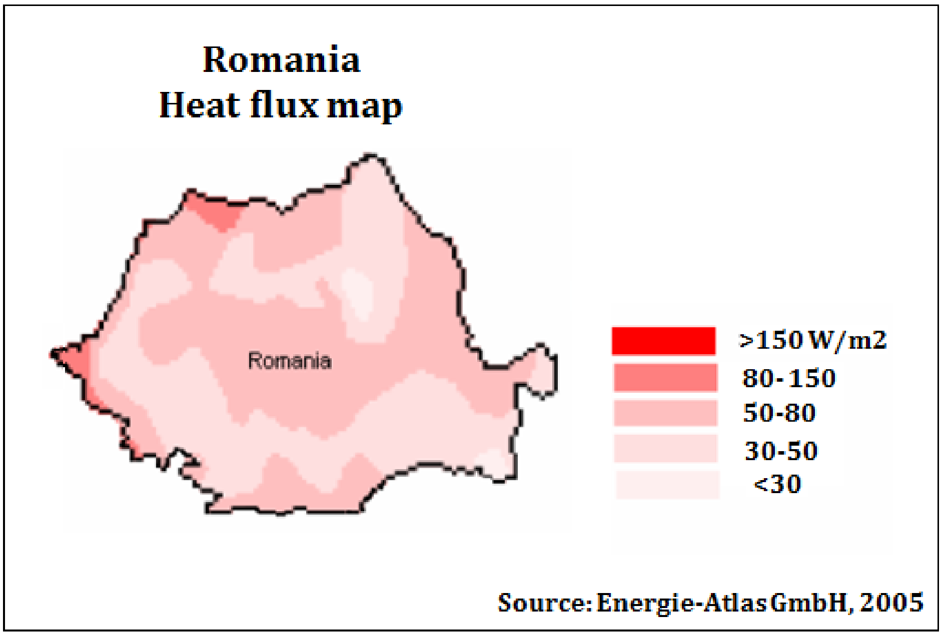

Figure 4.5. Geothermal Energy in Romania
Source: adjusted from (EBRD)

As shown in the previous subchapters, the Romanian renewable energy sources hold an important energy potential.

Geothermal and micro-hydro potentials are relatively small compared to the other resources, so for the renewable energy scenario, geothermal and micro-hydro will not be considered into the preformed simulation.

The major contributors of the theoretical technical potential of renewable energy resources are wind, biomass and solar and because of their abundance in Romania, these resources will be modelled further on in the sustainable sources scenario simulation.

5. Simulated Data and Results

This chapter is composed of two subchapters in which scenarios are presented. In the reference scenario the actual situation was simulated and in the alternative scenario, the development of renewable energy sources was simulated and analysed and at the end conclusions were drawn.

a. Reference scenario

The simulations and the various scenarios are performed in LEAP (Long range Energy Alternatives Planning) software, an energy and environmental policy analysis tool.

The efficiency and historical production data is derived from IEA World Energy Balances. The lifetime, interest rate, maximum availability and capacity credit are values assumed by the Stockholm Environment Institute.

In the simulation, the projected assumed growth per year is 1,2% for coal, 3,2% for natural gas, 0,6% for hydro and 1% for nuclear.

This baseline scenario is constructed without considering the development of renewable energy sources in the future and reflects just the development of actual used resources for electricity generation.

In order to obtain an accurate simulation of the shares of resources in the electricity consumption, the available data provided by the TSO and found on (Sist.Energ.) is interpolated into the software. Actual available data of consumption is found 4 times a day, during each year, starting 2008 and it is averaged and after that interpolated into LEAP. It can be observed that the exported electricity in 2008 is bigger than in 2009 with 45% and bigger than in 2010 with 33 %. In all these years the production is overall higher than the consumption.

After the interpolation of the actual numbers for the years 2008-2010, the simulated graphical representation is the one shown in Fig.5.1.

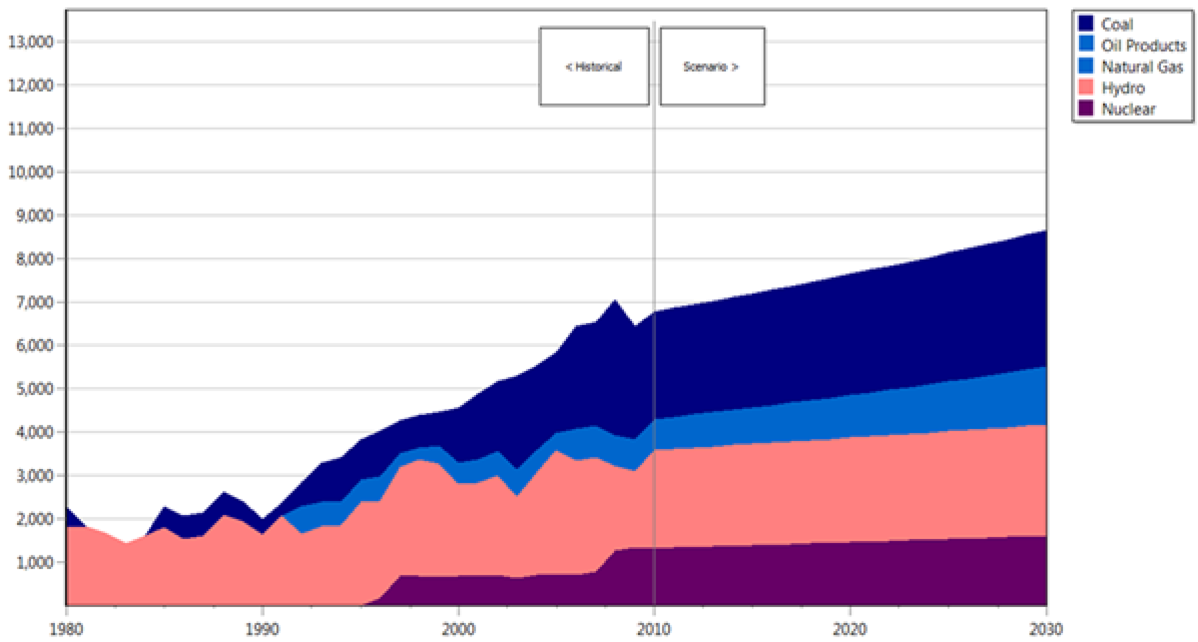

Figure 5.1.Simulated Historical and Future Scenarios Without Renewable Energy Sources

It can be observed that the dependency on coal, natural gas and nuclear resources will increase in the future. Having this in mind, considering the limited availability of polluting resources and considering that some power stations need to be closed in the near future through decommissioning programs, alternative solutions have to be developed and implemented.

The alternative scenario presented in the next subchapter provides another option for the resources of electricity generation in Romania.

b. Alternative scenario (renewable energy scenario)

In the alternative scenario projections of the three most important types of renewable energy sources are considered: wind, solar and biomass. Projections data that were afterwards interpolated into LEAP are obtained from a report of an independent consultancy company specialized in energy and international finance consultancy. The graphical representations of these projections are shown in Fig.5.2. Fig.5.3. and Fig.5.4.

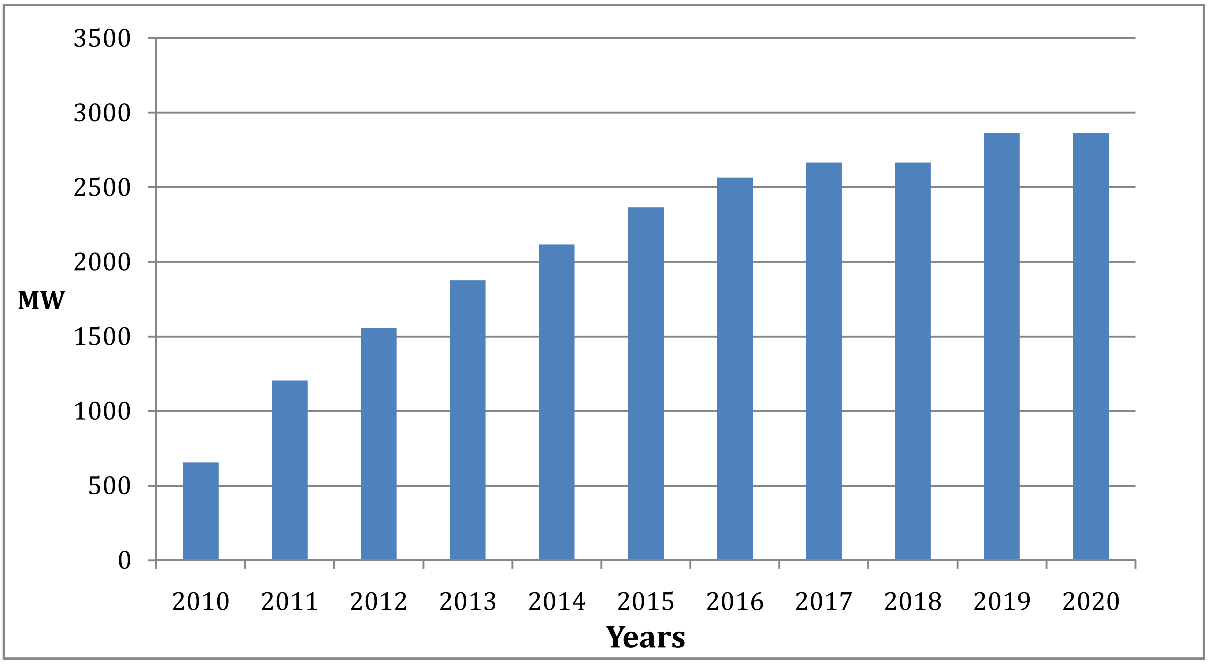

Figure 5.2.Projected Growth of Wind Energy Development in Romania (period 2010-2020)
Source: Own creation with data obtained from (Inv.E. 2010)

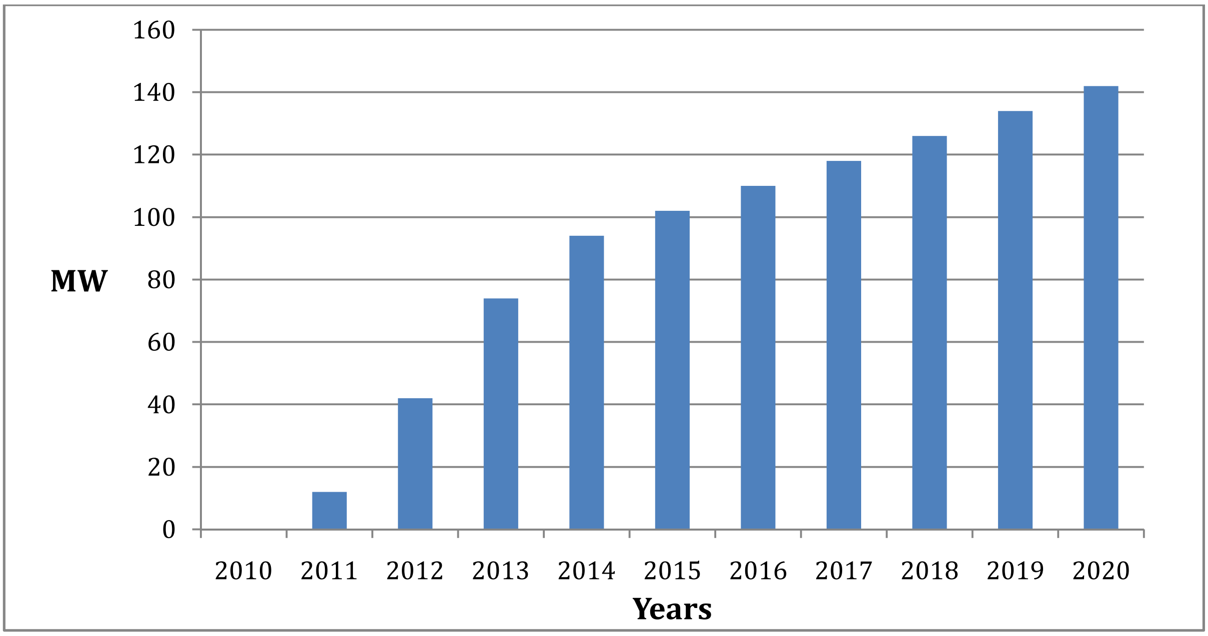

Figure 5.3.Projected Growth of Solar Energy Development in Romania(period 2010-2020)
Source: Own creation with data obtained from (Inv.E. 2010)

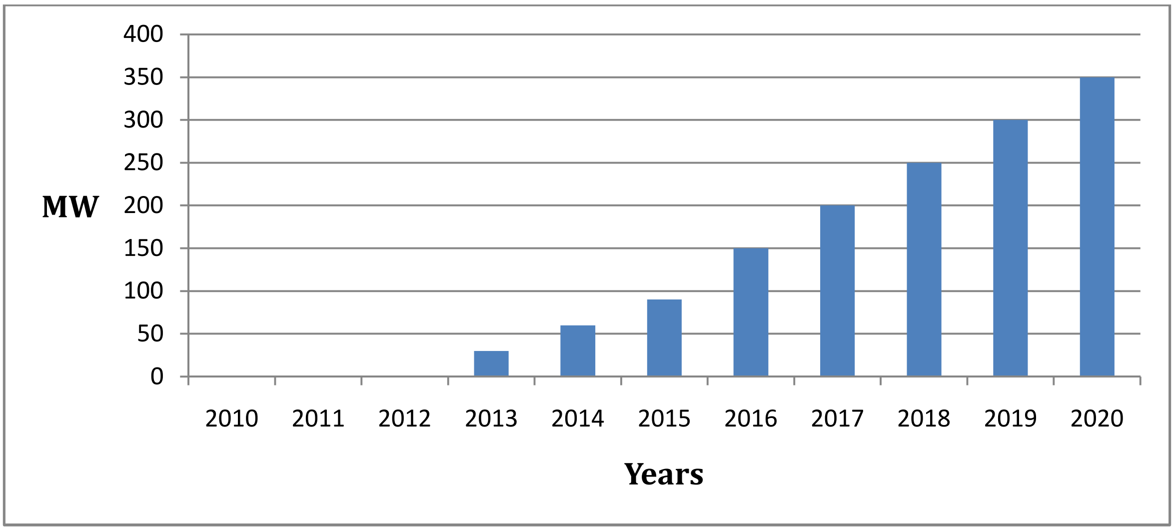

Figure 5.4. Projected Growth of Biomass Development in Romania 2010-2020
Source: Own creation with data obtained from (Inv.E. 2010)

After interpolating the projections for the renewable energy sources considered: wind, solar and biomass, the following graphical representation is the obtained, Fig.5.5.The projections are available only until 2020, so an approximation is made in the following way: from 2020 until 2030 the wind and biomass capacity is raised with 10%, and solar capacity is increase with 50%. The bigger increase in the solar capacity is justified by the continuous development in the photovoltaic technology and efficiency.

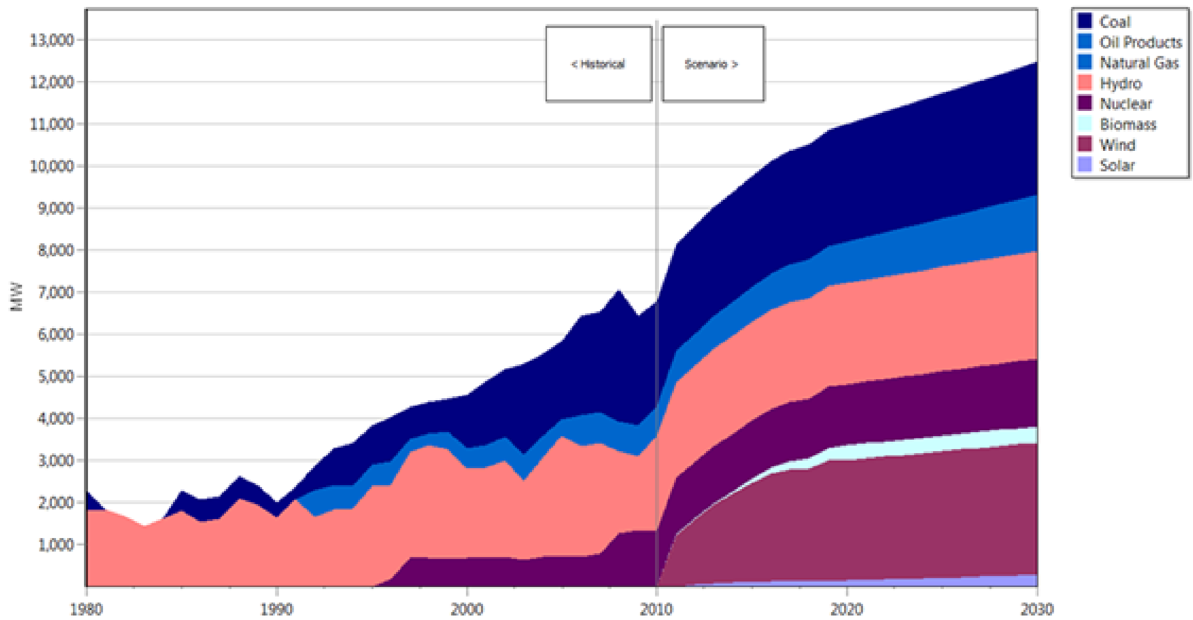

Figure 5.5. Simulated Historical and Future Scenarios with Renewable Energy Sources

Generation capacity

In the graphical representation (Fig.5.6.), obtained from the simulation it can be observed an increase in the electricity generation capacity due to the input of renewable energy sources. On the graph, coloured in red is the reference scenario capacity, and coloured in blue is the renewable energy scenario.

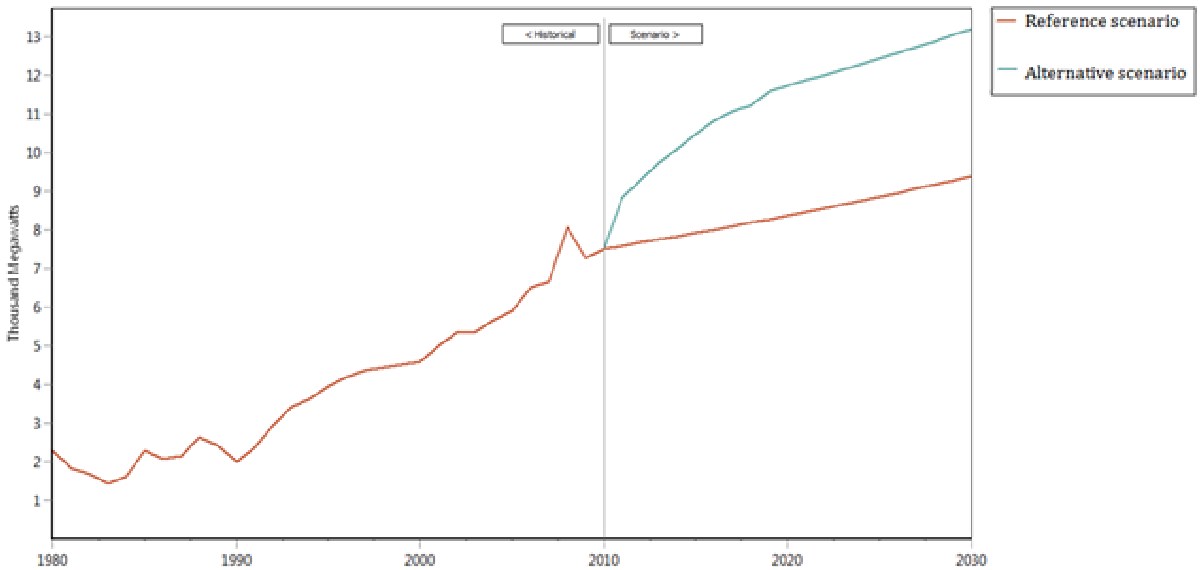

Figure 5.6. Generation Capacity representation in the Reference and Alternative Scenario

Hypotetical 'no coal' scenario

An hypotetical scenario is created and the coal usage in electricity production is theoretically set to zero starting with the year2011, as shown in Fig.5.7.

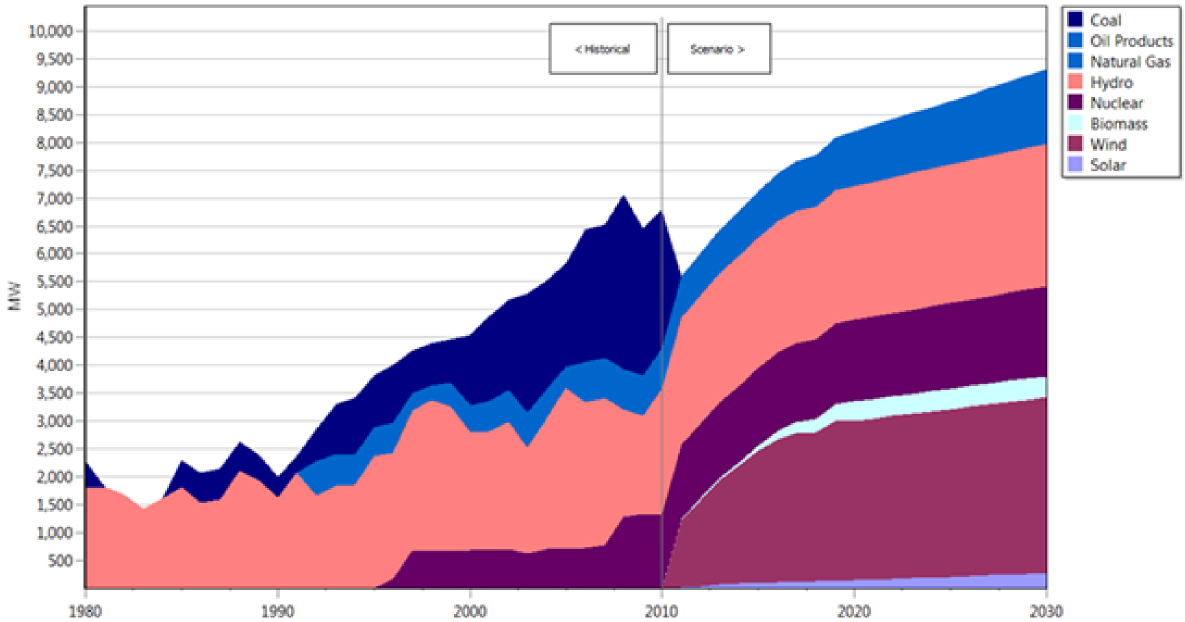

Figure 5.7. Simulated Historical and Future Scenarios with Renewable Energy Sources and with No Coal starting the year 2011

The hypotetical solution is to replace totally the coal usage from the year 2011 and to generate electricity through renewable energy sources.

Comparing the electricity production capacity from the reference scenario shown at the beginning of the chapter in Fig.5.1. with the hypotetical scenario in Fig.5.7, it can be observed that the capacity of electricity generation using wind, solar and biomass, combined togheter can hypothetically replace the total usage of coal.

Considering the important Romanian coal resources and the fact that an important part of its electricity production is based on coal, the total replacement of the coal until 2030 will not be possible.

This hypothesis was created in order to emphasize the importance of renewable energy sources in the electricity production and to demonstrate that the coal resources can be replaced by the wind, solar and biomass resources.

National targets

Data from the alternative, renewable energy scenario is collected from the simulation for the years 2015 and 2020 in order to verify the targets proposed by the National Plan of Action for Renewable Energy of achieving the following percentage electricity produced from renewable energy sources: 35% for the year 2015 and 38% for 2020.

The charts presented in Fig.5.8. are obtained. This figure is presenting the renewable energy sources used for electricity production in the years 2015 and 2010.

As it can be observed, half and more than half of the electricity production by 2015, respectively 2020 is obtained through renewable energy sources, so it can be concluded that the targets, of 35 respectively 38% electricity produced from renewable energy sources, are successfully overfulfilled. It was thus shown that with the development of its wind and solar resources, Romania can achieve its national proposed targets for using renewable energy sources in the electricity production.

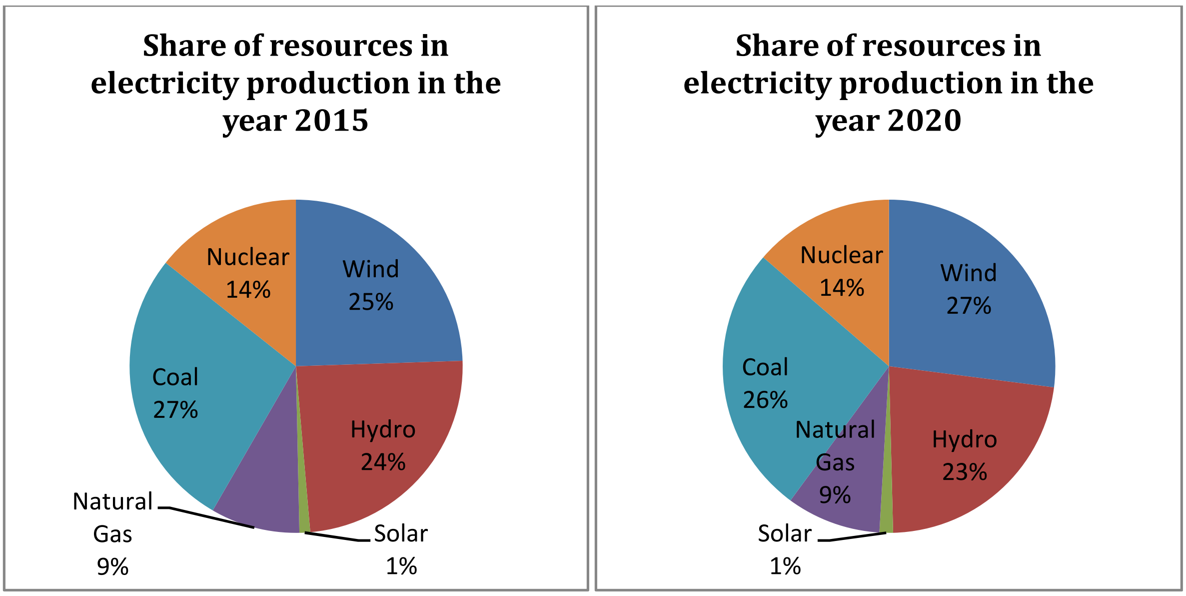

Figure 5.8. Share of Resources in Electricity Production in the Years 2015 and 2020
Source: Own creation using data from LEAP and (Sist.Energ.)

Costs

The capital costs and the operation and maintenance costs are obtained from (Energinet, 2010) and are interpolated into LEAP. The simulated graphical representation of the costs is the one presented in Fig.5.9.

It can be observed that an initial investment of 2,1 billion euros is necessary in the case of the renewable energy sources development. The simulated representation shows that in time the costs will drop compared to the actual resources costs for electricity generation. It is a relatively big initial investment in renewables, but just after ten years it will have considerable advantages compared with the reference scenario of electricity production, through low operational costs and sustainability.

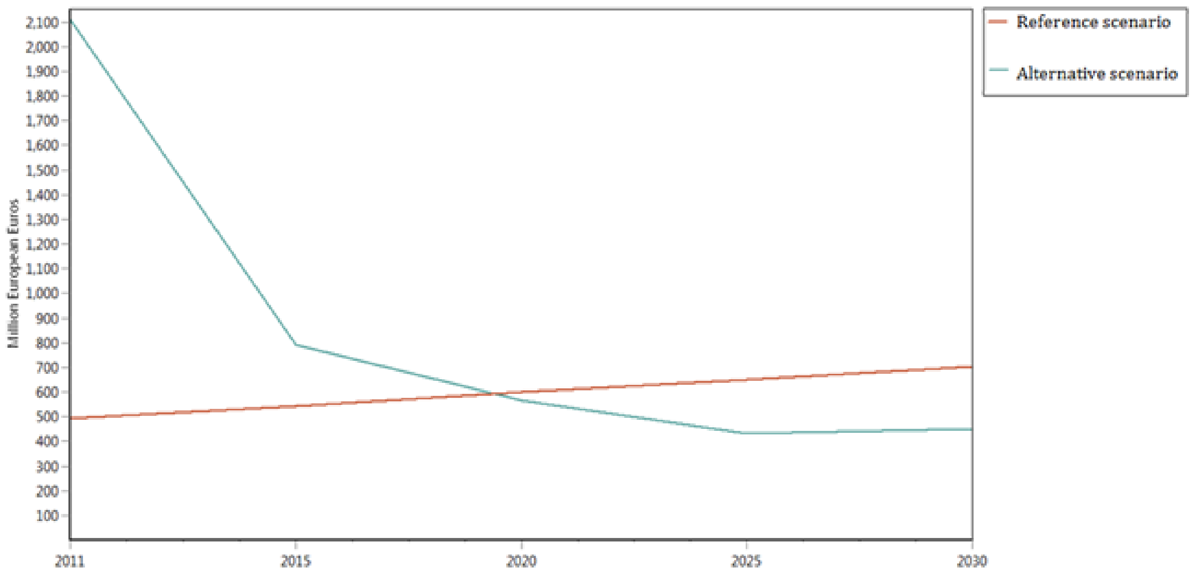

Figure 5.9.Total Costs, in Million Euros, in the Reference and Alternative Scenario

Greenhouse gas emissions

In the near future, the development of renewable energy sources as wind and solar can have positive outcome in reducing the usage of fossil fuels and can have a major role in reducing the greenhouse gases emission. The simulated graph in Fig.5.10., shows a major decrease of greenhouse gas emsissions in the scenario that uses renewable energy sources for electricity production.

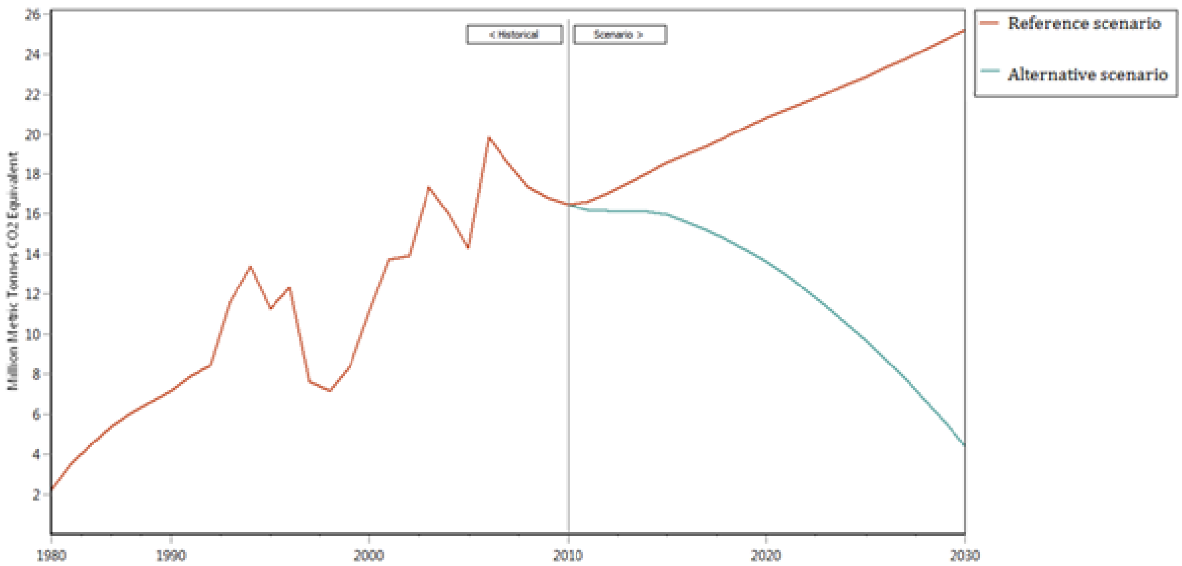

Figure 5.10.Reference and Alternative Scenario Representation of Greenhouse Gas Emissions, in Million Metric Tonnes CO2 Equivalent

By adopting the sustainable alternative scenario, Romania can increase its generation capacity, can easly achieve the national adopted targets for the amount of renewables in electricity production, and can lower its greenhouse gas emissions. It was shown that with an initial investment in the development of sustainable energy sources, on the long run the country will have important benefits.

6. Reflections and recommendations

It is absolutely necessary for our common future that renewable energy issues should be incorporated into long term planning processes, through projects in urban and rural locations, varying in size from domestic to the commercial scale.

As shown in the introduction, more than half of the greenhouse gas emissions are related to the energy supply and use, so by using our technological capabilities in exploiting the renewable energy resources through our future planning processes, we will be able to reduce the greenhouse gas emissions and to minimize the consequences of the anthropogenic pollution. An improvement into the energy supply will be the usage of cleaner fossil fuels such as uranium and natural gas in order to replace coal and heavy oil utilisation.

The development of harnessing the wind, biomass and solar resources available in Romania could have a major contribution in achieving the national targets proposed for the amount of renewable sources in the electricity production.

A development trend of Romania should be accomplished by improving the energy efficiency and utilizing the optimum allocation of resources.

Further on, the production based on renewable resources could be encouraged and promoted because the renewable energy sources are reducing the dependency on the imported fuels and are far less polluting.

Renewable energy facilities are requiring less maintenance than technologies based on non-renewable sources, the costs of operation is also smaller and the RES are abundant and the generation of excess renewable energy could be sold to the national grid for a profit.

It was shown in this report that the majority of the most important stakeholders that have important influence on the development of the energy projects or programs are influenced by the state. This fact shows that a good functioning of the state and its related institutions and aspects will help and encourage a proper and beneficial evolvement of the energy related projects.

For the moment, each Ministry (Ministry of Economy, Ministry of Environment, the Ministry of Agriculture and Rural Development, the Ministry of Transport, the Ministry of Administration and Internal Affairs, the Ministry of Finance) should identify its role and its measures in achieving the national objectives.

As for the future, the necessity of a Ministry of Energy is a vital one. The new established ministry will be important for a provision of clean, sustainable and affordable energy and also for the development of the national energy policies. Further on the new established ministry will guarantee that the national proposed objectives will be successfully accomplished. The Ministry of Energy should implement measures that will support projects and programs that will deal with the growth of the energy efficiency and the use of renewable energy and should support the restructuring and privatisation in all the sectors.

The new formed ministry should also stimulate the development of renewable energy sources usage by facilitating the incentives process.
The competitiveness must be encouraged by continuing the development of competitive energy markets and tradable green certificates.

The prices should be formed in a free competition and the market mechanism should be transparent and should be supervised by independent market operators.

The Romanian Energy Regulatory Authority (ANRE) should have autonomy and independence and it must be politically neutral, because at the moment it appears to be politically influenced, fact that could have an impact on the decision making inside it. Also the methods used for selecting ANRE staff will have to guarantee the professionalism of its members.
The state support on investments is also important and the state position on supporting the investors should remain constant, without changes that could affect the investment process.

Projects involving renewable energy could bring economic benefits to many areas in Romania and the development of RES projects is a good solution because in Romania there are large areas with low population density that could be exploited for resources.

Unprofitable agricultural regions could be converted and used for renewable energy production.

The development of projects related to Carbon Capture and Storage (CCS) technology should be supported by the Government and encouraged through incentives.

The renewable energy industry projects will create new job opportunities and will increase the rate of employment.

Educational programmes describing the role of renewable energy and of the new technologies are necessary to be created and developed, and the research and development of applicable projects should be supported and further enhanced.

7. Conclusions, limitations and future work

Conclusions

An overall presentation of Romania is made and the concept of sustainable development and its strategies are presented. The important stakeholders in the country are categorised and described, and the energy law in Europe and its applications in Romania are presented. A SWOT analysis of the current situation in the Romanian energy sector is performed and the sustainable potential of the country is described.

A presentation of the actual reference scenario is made and a sustainable alternative scenario is simulated. The simulated graphs are analysed and interpreted and the necessary conclusions are drawn.

Limitations

The focus of this report was to utilize the available resources only for electricity production, thus thermal energy was not taken under consideration.

The potential of small hydro is not considered in the software simulated projection scenarios. Also, geothermal and solar thermal development was not further used in the simulation because the focus was on the electricity production.

The data used for simulated projection of the development of renewable energy sources was obtained from a consultancy company report.

The social impact of implementing the renewable energy source or the job creation was not studied in this report.

Future work

- As future work, the potential of renewable energy sources for producing heat and the possibility of combined heat and power (CHP) could be studied.

- The social and economic impact of implementing the new sustainable solutions could be analyzed in the future.

- The impact of renewable energy programs development on jobs creation could be studied.

- Methods of attracting and encouraging new investors to invest in the Romanian energy sector could be studied.

- A detailed study in the field of the Romanian economic development could also be performed in the future.

- A more in depth analysis of the current situation of CO_2 emissions could be performed and technological solutions for solving the problems of carbon emissions could be suggested.

- The regulations for the building codes should be taken under consideration and measures to reduce the energy consumption could be proposed and studied.

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APPENDIX 1.Photovoltaic installations

Photovoltaic (PV) installations can harnesses one of the greatest energy sources on earth – the sun. Solar PV generates electricity in well over 100 countries and continues to be the fastest growing power-generation technology in the world.

It is a technology that utilizes the sun's energy to generate direct current (DC), which is changed into alternating current (AC) by inverters before it is used in custom appliances.

Photovoltaic cells consist of thin layers of positive and negative type semiconductors, which are typically made of silicon. The particles in the material of the negative semiconductors are made to contain a *surplus of free electrons* while the particles in the material of the positive semiconductors contain a *deficit of free electrons*. Layering these different type semiconductors together creates an electric field that can transform the energy harnessed from the sunlight into electrical power.

Photovoltaic technology has some general advantages and disadvantages, which are listed below:

Advantages:

- PV are using no fuels in order to produce electricity
- There are no emissions from electricity generation
- They have a long lifetime (30 years or more)
- PV modules contain no moving parts and are easy to install and operate

Disadvantages:

- PV has high initial investment costs
- The output is directly proportional with the solar radiation and is not controllable

- They utilize a relatively high land area per kWh produced

  (Danish Energy Authority 2005)

Looking at the environmental impact of harnessing the sun by PV, no emissions are to complain, however some models of PV cells such as Copper Indium Selenide , Cadmium Teluride (CIS, CdTe) contain toxic chemicals like Cadmium, which can be released into the environment in case of fire (Boyle 2004, 95). As environmental friendly recycling methods are not standard in the area it is the operator's duty keeping sustainability premises in mind when deconstructing the plant. Although the mentioned environmental threats are assured, Boyle (2004, 95) states that „the environmental impact of PV is probably lower than that of any other renewable [...] electricity generating system."

APPENDIX 2.Biomass applications

Biomass Applications can be grouped into the following main market segments:

- substitution of part of the fossil fuels in existing district heating schemes (wood chips)
- enhanced uses of biomass as industrial fuels (wood chips and logs as industrial fuel for steam or hot water boilers) instead of oil
- improved uses of biomass for new district heating schemes for small towns and villages near the resources, in the countryside, where the population has no access to central co-generation or gas supply
- uses of straw and other agricultural by-products in appropriate biomass boilers for heat supply of farms and small villages (in the medium term). (Inv.E. 2010)

APPENDIX 3.Geothermal energy

Regarding the environmental impact it is to be said that geothermal power generation can result in surface disturbances like changed patterns of hot spring activities including disappearance. Also noise, heat and steam as well as chemical discharge into the air, ground and surface water are consequences to be considered. While all those impacts can be reduced by the right choice of technology, a matter which is impossible to avoid, is the optical impact geothermal appliances have on very rare landscapes (Ármannsson and Kristmannsdottir 1992, 869-875). Thanks to the implementation of medium temperature power plants (binary cycle), some new locations have engaged in geothermal power plant development (especially CHP plants, due to the more economical usage). Such areas are found in the following the west of the country.

Estimated geothermal electricity potential

Although the utilization of geothermal energy can be considered broadly cost-competitive, it has a relatively high investment cost as one disadvantage. However, its availability is high and it has stable production. These are significant advantages compared to wind or solar power production. The lack of geological availability can be solved by the Enhanced Geothermal System (EGS), which allows for low-to-medium temperature applications via binary cycles and cascading usage.

Applications for geothermal energy can be grouped into three main market segments:

• Market for district heating for urban areas and possibly for villages.

• Market for thermal applications within the primary, secondary and tertiary sectors

• Market for power generation connected to the grid in case of high enthalpy sources.

According to the discussion on economic potentials, the top priority is the use of geothermal sources for thermal applications existing district heating supply system in the cities nearby the geothermal fields and in new DH schemes for smaller towns and large villages. Also could be used for thermal applications for industrial or agricultural uses. (Inv.E. 2010)