Die approbierte Originalversion dieser Diplom-/Masterarbeit ist an der Hauptbibliothek der Technischen Universität Wien aufgestellt (http://www.ub.tuwien.ac.at).

The approved original version of this diploma or master thesis is available at the main library of the Vienna University of Technology (http://www.ub.tuwien.ac.at/englweb/).

MSc Program
Environmental Technology & International Affairs

The Potentials of Renewable Energies in Transition Economies

An investigation of industrial processes in Serbia

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
O.Univ.Prof. Dipl.-Ing. Dr.rer.nat. Paul Hans Brunner

Jürgen Angleitner-Flotzinger

9518448

Vienna, 17 June 2009

CONTINUING EDUCATION CENTER

TU VIENNA

diplomatische akademie wien

Vienna School of International Studies

École des Hautes Études Internationales de Vienne

Affidavit

I, **JÜRGEN ANGLEITNER-FLOTZINGER**, hereby declare

1. that I am the sole author of the present Master's Thesis, "THE POTENTIALS OF RENEWABLE ENERGIES IN TRANSITION ECONOMIES - AN INVESTIGATION OF INDUSTRIAL PROCESSES IN SERBIA", 72 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

Vienna, 17.06.2009

____

Signature

Acknowledgements:

My gratitude goes to all those persons who were involved in the development and realisation of this Master Thesis. Professor Paul H. Brunner and Professor Manfred Grasserbauer from the Vienna University of Technology supported me in a competent and committed way during all phases of the thesis. The case study was only possible through the support of the United Nations Industrial Development Organisation. The department of Cleaner Production provided me with valuable information and contacts. Director Leuenberger and Ms. Schwager who are working at UNIDO's headquarters in Vienna were willing to support me as much as their time allowed. In Serbia Dr. Branko Dunic and Bojana Vukadinovic from the Cleaner Production Centre Serbia in Belgrade, were offering their help in order to find an appropriate case study. During two visits to Serbia they were guiding me to interesting companies they are working with in their activities of the Cleaner Production Centre. I would like to express special thanks to Mirjana Stamenic from the University of Belgrade who provided me with valuable information with regard to renewable energies in Serbia. My contact person at Sojaprotein, the company treated in the case study, was Jelena Lucic. Despite her full time table she found time for my requests of specific information and data.

Last but not least I would like to thank my parents and all the other members of my family who supported me not only during the time of my thesis but during the entire time of my studies.

1 Introduction

Climate change is considered to be one of the most urgent and challenging issues humanity is currently confronted with. For the first time in the history of planet Earth, a species is able to influence the ecosystem in a way that conditions of life could become hostile for this very species itself. Mankind is consuming a lot of energy for the maintenance and development of its modern lifestyle – a lot more energy than would be sustainable. The use of fossil fuels has extended possibilities and limits, they made industrial revolution possible and are at the same time the indirect driving force for discoveries in many different fields. Even population growth can be brought in relation with the use of fossil based energies.

Today, according to the opinion of experts, mankind can no longer continue to increase the concentration of green house gases, especially Carbon Dioxide in the atmosphere without endangering its own future. This is why in many countries and sectors, people engaged in all different fields of science and technology and in social and political science are searching for new solutions to find a way out of this crisis. One of the sectors contributing most to Greenhouse Gas Emissions is without any doubt industry. Industrial production requires large amounts of energy – these originated during the last 150 years to the by far biggest share in fossil fuels. This practice will no longer be possible to be continued in the usual way due to climate change and due to scarcity of resources of primary energy.

Today fossil fuels can be substituted by renewable energies which are neutral with regard to their CO2 balance. However these resources are only available in a sustainable way. In order to keep the current standard of life energy efficiency needs to be increased in order to decrease energy consumption. Only a lower level of energy global consumption is sustainable and can be supplied by renewable energies.

This Master Thesis is treating the potentials of renewable energies in the industrial sector of transition economies – a special emphasis is placed on Serbia. The first part provides general information on Serbia and Renewable Energies. An overview of Serbia is given with regard to general data as well as with regard to energy. After a general description of Renewable Energies, Biomass is examined more closely since this form of Renewable Energy is the one used in the case study. The case study represents the second part of the Thesis. A soy processing company in Serbia is using renewable energy for steam production since almost two years and has made good experience. It is shown that substituting fossil fuels by renewables, not only brings a reduction in greenhouse gas emissions – it also brings an economic benefit. The investment into technology of renewable energy is not only discussed at the technical and material level but also with regard to the financial and legal aspects. In the third part of the thesis these issues are discussed as well as the topic of technology transfer under United Nations Framework Convention on Climate Change.

The goal of this Master thesis is to show in a concrete and concise manner that there are viable solutions to the problems of climate change and energy scarcity, which have already been implemented and tested. These solutions are not simplistic and cheap – they need to be found and developed on a case to case basis by taking into consideration the specific potentials of renewable energies in a certain region. Once assessed and implemented, renewable energies and appropriate technologies can give a valuable contribution to the mitigation of climate change, increase energy security and independence and bring a considerable economic benefit.

2 Methodology

For the Master Thesis different methodologies have been used. One important part was the acquisition of data by direct contact with a company used as an example for the successful implementation of technologies using renewable energies (Environmentally Sound Technology). In order to find such a company that not only was interested in the use of renewables but was also willing to share their data, two visits in Serbia have taken place.
The first visit was in February 2009. During this visit the National Cleaner Production Centre (CPC) of Serbia was visited and several scientific and governmental institutions dealing with renewable energy in Serbia. The CPC assisted in finding an appropriate company. From their experience with companies that are or were in their projects of assessment, they have good contacts to different industrial sectors. Two companies have been visited in February: UMKA, a cardboard producing company and Stark, the biggest producer of confectionary in Serbia. Both companies are located in Belgrade. Due to organisational reasons one company only could be visited in March – this is why a second visit was necessary.

The second visit was to Sojaprotein, a company that is processing almost Serbia's entire soy harvest. This company was immediately ready to share confidential data for the Thesis: their cleaner production assessment report and special data which are concerning the production of steam and energy. Further data were provided by electronic correspondence (e-mail).
A considerable part of the thesis is based on scientific literature of scientists of mainly Serbian origin. The access to this kind of literature was to a large extent organised or directly provided by the University of Serbia. Some of the articles even have not been published yet.
Another part of the Master Thesis is based on data accessible on the World Wide Web on the homepages of international organisations and institutions. Some data are just from data bases, some have been published in reports or other publications of these institutions.
A smaller part of the thesis is based on interviews that either took place in the Sojaprotein factory or that were held with employees working for institutions that are dealing with energy or technology transfer. Information concerning technology transfer has to a large extent been acquired by study material from the Vienna University of Technology, provided by the Institute for Water Quality, Resource and Waste Management. Other information used, was provided by the United Nations.
An important tool for the analysis of data was STAN, special software also provided by the institute for Water Quality, Resource and Waste Management. STAN helped in the practical handling of data and processes and their appropriate graphical presentation. With the help of this program a Material Flow Analysis was carried out and a graphical presentation of all the different process in the case study was created.

3 Serbia in facts and figures

3.1 Geography, Demography and Economy

The Democratic Republic of Serbia is located in South-eastern Europe; it is a continental country with a total surface of 88.361 km². Its exact geographical position is between 41°53’ and 46°11’ Northern Latitude and between 18°49’ and 23°00’ Eastern Longitude (Republic Statistical Office of Serbia, 2003). In 2007, according to the World Bank, Serbia had 7,38 Mio inhabitants with an annual population growth rate of -0,4 % (World Bank, 2009). The biggest city and at the same time the capital of Serbia is Belgrade with 1,7 Mio inhabitants (metropolitan area) followed by Novi Sad, the Capital of the region of Vojvodina and Serbia’s second largest city, with 334.000 inhabitants (City of Belgrade Institute for Informatics and Statistics, 2006).

Between the years 2000 and 2007 Serbia’s GDP rose from 8,96 to 40,12 billion US $. In the same period of time annual GDP growth rate rose from 4,5 to 7,5 % and inflation decreased from 81,0 % to 6,8% annually (World Bank, 2009).

3.2 Energy Supply and Consumption

Generation and final consumption of electricity:

In the year 2005 Serbia consumed 36.474 GWh of electricity. The biggest share of electricity was generated by thermal power plants (65,5 %), followed by hydro power with 33 % and by combined heat and power plants (CHP) with a share of 1 %. Only 0,5 % of electricity was realised by auto-producers (STATSERB, 2006). In figure 1 these figures are graphically shown.

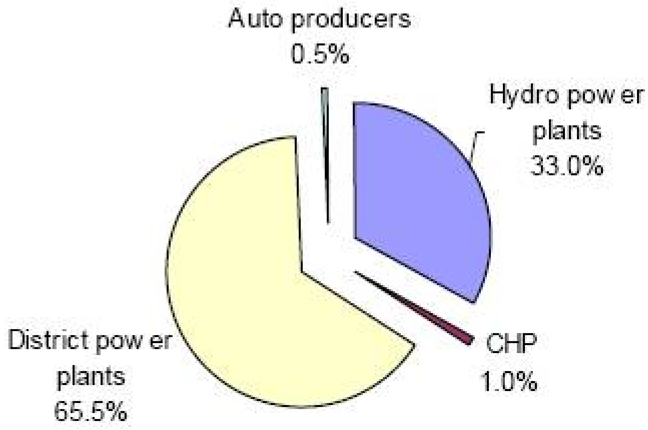

Figure 1 Shares of electricity generation in Serbia by producers (Source: STATSERB, 2006)

At the same time, in 2005, in final consumption of electricity households participated with 55,3 %, industry as second biggest consumer with 22,4 %, other users with 19,3 % construction with 1,2 %, transport with 1 % and finally agriculture with only 0,8 % (STATSERB, 2006). Figure 2 shows the shares of different consumers in electricity consumption.

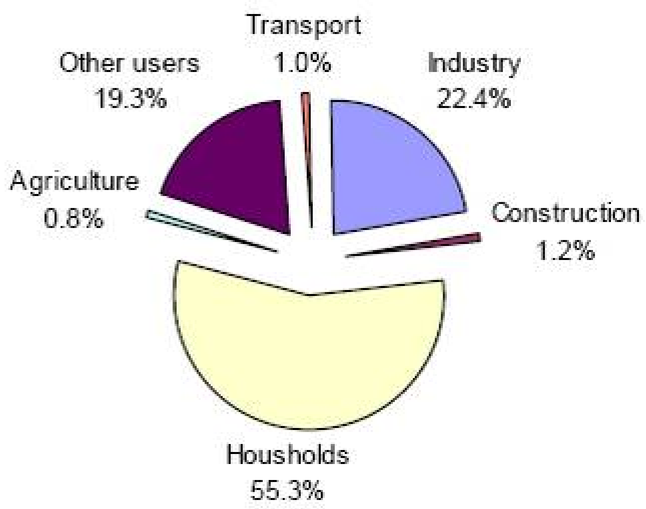

Figure 2 Shares of final consumption in Serbia by different consumers (Source: STATSERB, 2006)

Generation and final consumption of heat energy:

In the year Serbia consumed 48.799 TJ of heat energy. The greatest production of heat was realised by auto-producers (47%), closely followed by district heating plants with 45,4 %. 4,4% of heat energy was produced in CHPs and 3,2% in thermal power plants (STATSERB, 2006). Figure 3 shows these shares graphically.

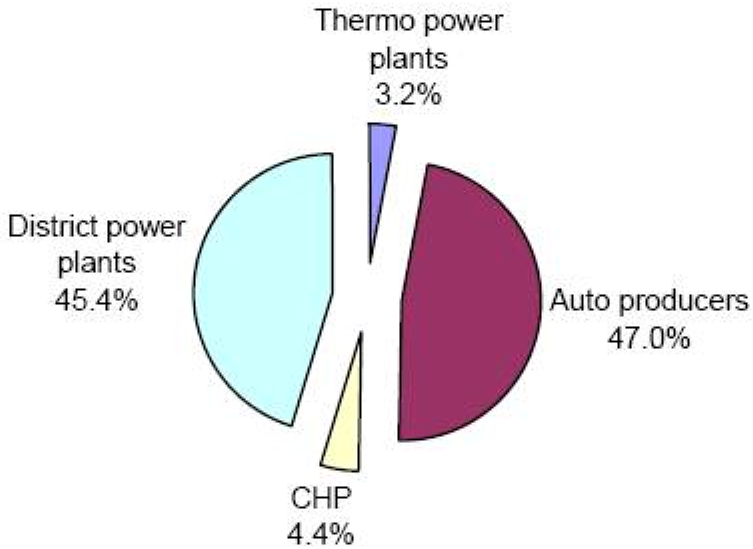

Figure 3 Shares of different producers in total generation of heat energy (Source: STATSERB, 2006)

Heat energy was in the same year mostly consumed by industry (56,1 %), followed by households with 36,6 %. Other users held a share of 6,8 % and agriculture just 0,5 % (STATSERB, 2006). Figure 4 shows the different shares in final heat consumption by consumers.

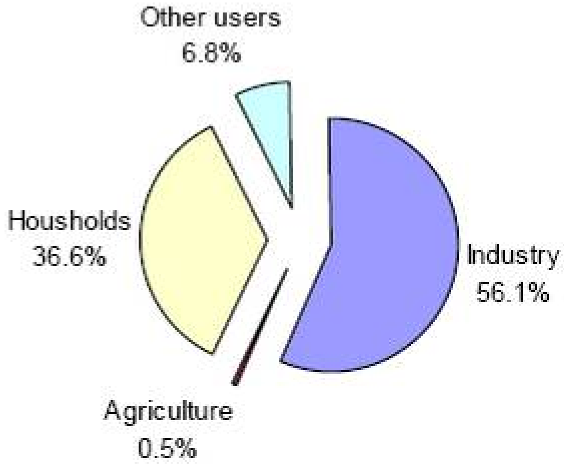

Figure 4 Shares of different consumers in total final consumption of heat energy (STATSERB, 2006)

With regard to different fuels used for the generation of electricity and heat energy the by far biggest share is held by coal: 82 %. Natural gas holds a share of 10 % followed by petroleum and petroleum products with 7 % and other fuels with only 1 % (STATSERB, 2006). In Figure 5 these figures are shown graphically.

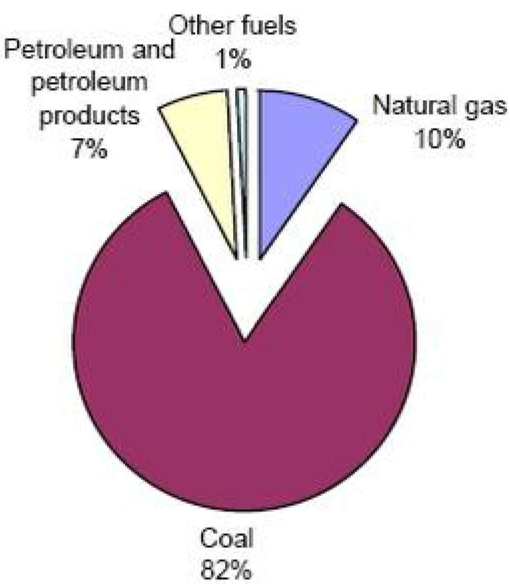

Figure 5 Shares of different fuels in Serbia's total fuel consumption (Source: STATSERB, 2006)

With regard to plants and other places where fuel is used for power generation biggest share of consumption takes place in thermal power plants: 81,2 %. District heating plants hold a share of 8,4 %, auto-producers consumed 8,2 % and CHPs finally consumed 2,2 % (STATSERB, 2006). In figure 6 the share of different consumers in total fuel consumption is shown graphically.

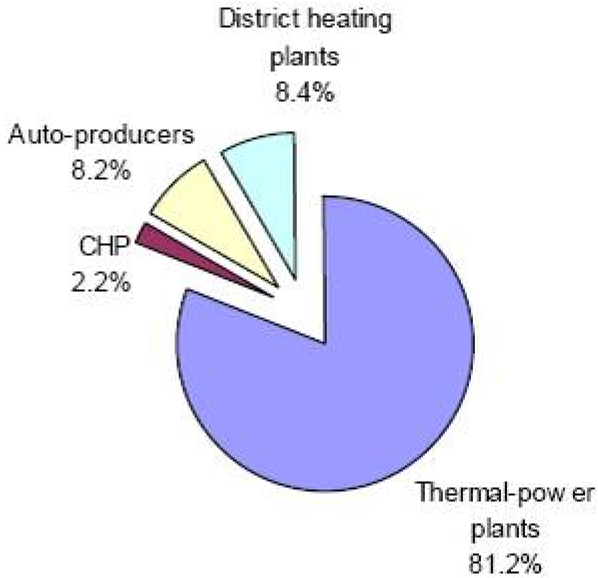

Figure 6 Shares of different plants in total fuel consumption (Source: STATSERB, 2006)

For all different types of energy generation, different kinds of plants, all different scales, the Statistical Office of the Republic of Serbia calculated an overall energy efficiency of 43,6 % in thermal electric energy and thermal energy generation.

4 Renewable Energies

In this chapter first an overview of different source is given. In a second step the potentials of renewable energies in the national territory of Serbia are described with a special emphasis on Biomass. In a third step the importance of resources of biomass is described at a global level and technologies for their energetic use are taken into consideration.

4.1 Overview of sources

Renewable energies can be classified in three main categories which correspond to the basic source of their origin. One can differentiate with this regard between renewables that are driven by the sun, by gravitation or by the heat of the earth. Geothermal energy is based on the heat of Planet Earth's core whereas tidal energy is based on the force of gravitation. All other renewables are driven by the radiation of the sun: solar thermal, photovoltaic, biomass, wind and hydropower. In this short overview of sources, each form of renewable energy will be shortly described.

Geothermal Energy is generated deep within the Earth. Radioactive decay and high pressure deep in the interior of our planet generate heat, which rises to the surface through magma, molten rock. Where this magma gets in contact with ground-water it heats up the water. In that way the pressure of the groundwater lake is increased. Visible consequences of this mechanism are the phenomena of terrestrial geysers and submarine hydrothermal vents. Geothermal Energy can be either directly harvested at places where geysers are located or by drilling artificial wells. In both cases steam is used for the production of electricity by means of generators and for direct use. Heating houses, steam production in industrial facilities or drying processes are some examples for direct use of geothermal energy. To work in a sustainable manner such a geothermal power plant can only use as much steam as water is recharged. In order to increase the amount of energy and steam available, groundwater is recharged by artificial drillings. Water is injected into the underground aquifer by pipes. Sometimes due to geological processes, patterns of geothermal activity in the Earth's crust shift naturally over time. In that case, use at a certain location comes to an end and geothermal activity is shifted elsewhere (Withgott and Brennan, 2008).

Geothermal energy can also be harvested at an individual level for households by so called heat pumps. A special liquid is circulating through pipes which are located under the Earth's surface. The temperature gradient between the underground and the surface is used to harvest heat which can be used for heating houses.

Tidal Power is driven by gravitational force. The moon, the Earth's satellite is acting gravitational force on the surface of our planet. This force is moving the water of the oceans at places with special topographic conditions the kinetic energy of the moving water can be used for the production of electricity. The principle of electricity production by tidal power is the same as the one which run-of-river power plants are based on. Energy is harvested by the difference in water level at high and low tide. There are power plants which use the flow of water in only one direction; other concepts use the flow in both directions. The most famous tidal power plant is the one in La Rance in France which is in operation since more than forty years. Other facilities are located in China, Russia and Canada and one new modern plant is planned in Great Britain.

Solar Energy can either be passively or actively used. In the first case, a building can be for example designed and placed in a way that is accumulates the maximum amount of solar radiation. This would mean for the northern hemisphere that big windows made of thermo glass are directed to the south, while the part of the house facing the north has only small windows and good isolation. However there are possibilities to collect solar energy actively. Either heat is directly used or with the help of physical processes electricity is produced.

Solar Energy can be actively harvested by **Solar Thermal** Collectors which are also called solar panels or flat plate solar collectors. These facilities consist of dark coloured, heat-absorbing metal plates mounted in flat boxes, covered with glass panes. Through the collectors, water, air or antifreeze solution is circulated by tubes. In that way, heat is transferred to the place where it is needed and used. Other facilities for the direct use of solar energy are for instance solar cookers and power towers. Solar cookers consist of a parabolic mirror. At the mirror's focal point one can use solar radiation for cooking. This technology is very likely to play an important role in developing counties where the intensity of solar radiation is high enough. There it could partly replace traditional fuel wood as source of energy. Solar towers are facilities for the production of electricity. Mirrors are spread across wide expanses of land to concentrate sunlight onto a receiver located on the top of the tower.

Heat is then transported through fluid-filled pipes to a steam-driven generator that provides electricity.

By making use of the photovoltaic or photoelectric effect, **Photovoltaic** Cells (PV) collect sunlight and convert it to electrical energy. Sunlight strikes one pair of metal plates (made of silicon) in a PV cell, causing the release of electrons. These electrons are attracted to the opposing plate by electrostatic forces. A direct electrical current (DC) is created which can be converted into an alternating current (AC) in order to be used for residential and commercial electrical power (Withgott and Brennan, 2008).

Organic material that makes up living organisms can be defined as **Biomass**. The source of energy is, as mentioned above, solar radiation taken up by photosynthesising organisms. These organisms are photoautotroph; that means they need solar energy, carbon dioxide and water in order to produce biomass by photosynthesis. All other organisms which are not autotrophic are depending on the uptake of organic matter by food. Biomass Energy can be harvested from many types of plant matter, including wood from trees, charcoal from burned wood, agricultural crops and combustible animal waste products such as cattle manure. One has to further distinguish between traditional biomass sources which are widely used in the developing world and "new" biomass sources such as bio ethanol, bio diesel or wood pallets. The first group is rather burned in a way that has a very low efficiency whereas the technologies used for the combustion of the second group provides for a higher and ever increasing efficiency.
In order to describe the major sources of Biomass Energy one can also distinguish between direct combustion for heating, Biofuels for powering vehicles and biopower for generating electricity. (Withgott and Brennan, 2008) The first group of Biomass Energy consists of wood cut from trees also called fuel-wood, charcoal and manure from farm animals. Vehicles can be powered by various Biofuels: one source can be ethanol which can be produced by corn or by the residue of sugar cane called bagasse. Another type of sources is soybeans, rapeseeds, other kids of crops and used cooking oil for the production of bio diesel. Finally, cellulosic ethanol can be produced out of plant matter that is treated with enzymes. The third group of Biomass Energy can be defined as biopower for generating electricity and heat. In this category a great variety of sources need to be mentioned: Crop residues, such as corn stalk or straw of different crops, forestry residues like for example wood waste from logging and processing wastes such as solid or liquid waste from sawmills, pulp mills and paper mills which are all

burned at power plants. Landfill gas and biogas from anaerobic digesters in which for example livestock waste from feedlots is fermented to methane are other good examples for Biomass energy with which heat and power can be produced. Finally one should not forget that the fraction of high caloric value of municipal solid waste can also serve as effective fuel.

Wind Energy is another form of indirect solar energy. The sun heats up air masses in different ways at different locations, which causes wind to blow. The power can be harnessed by wind turbines which convert kinetic energy partly into electrical energy. The device consists basically of a tower, three blades and a generator. These wind turbines are normally erected in groups, called wind parks or wind farms, at places with a certain potential for wind energy. So far most wind parks are located on land; only few devices are installed off shore even if the potential there would generally be much higher. The reasons for that fact are the technically unsolved problems caused by salt water: corrosion at electrical devices. Another issue is the high effort to erect the tower off shore on the sea ground and the transport of the electricity by cables to the place where it is used. Today generators of different size and power are available. Most generators today in use have a blade diameter of 66 meters and are constructed for a power of 2 MW. New devices have a diameter of 112 meters and are constructed for a power of 5 MW (Brauner, 2009).

Hydropower is another form of renewable energy driven by solar radiation. Water is evaporated from a water surface. By condensation water vapour is transformed into rain. These raindrops have a very high potential energy; they are accelerated by gravitational acceleration and fall on the Earth’s surface. Only the last meters of that potential energy can be used for the production of electricity in hydropower plants. In general there are two types of hydropower plants: storage hydropower plants and run-of-river power plants. In the first case water is stored in a storage lake located up to several hundred or thousand meters above the place where the turbine and the generator for the production of electricity are located. By means of high pressure pipes the water is transported to the power house where electricity is produced. In the second case, the run of river power plant, the kinetic energy of the flow of a river is used. The river is barred by a barrage made of concrete which allows the use of a small amount of potential energy. The water flows from the upper part of the barrage to the lower water level downstream and by doing so it accelerates a turbine that is connected to a generator for the production of electricity. Run-of-river power plants are used for the production of a basic load whereas storage power plants are only switched on for the production of peak loads. The latter ones can moreover be used for the storage of electricity stemming for example from wind parks. If there is too much electricity produced at a certain time of the day which surpasses the actual demand, electricity can be used to run a pump (which is the same device as the turbine) in order to pump up water from the power house to the storage lake. In that way electricity can be stored by water with a high potential energy.

4.2 Potentials of Renewable Energies in Serbia

The potentials of renewable energies in the energy supply of Serbia can be found in several renewable sources. According to the Energy Efficiency Agency of Serbia (SEEA) the total potential without solar energy and large hydropower plants is estimated on about 3,2 Mtoe (Mega Tons Oil Equivalents) or about 25% in relation to total primary energy consumption (Kragic, 2008). Biomass with an absolute potential of about 2,6 Mtoe holds the biggest share in all renewable sources followed by wind with about 0,2 Mtoe, Geothermal which accounts approximately 0,18 Mtoe and Small Hydro Power Plants (SHPP) with a potential of 0,15 Mtoe. The solar potential can only be given in a potential per square meter – for Serbia the average flux of solar energy is about 0,1 toe/m^2.

4.2.1 Biomass:

As stated above, the potential for biomass is about 2,6 Mtoe. This absolute number is shared with 60% by biomass from agriculture and with 40% by biomass from forestry (wood). Currently biomass is already used by one factory in Serbia for the production of bio-diesel: the production of this factory is about 100.000 t/a. Another use of biomass already in practice is heating. For heating, since most applications are on a small scale, domestic level, no precise data are available concerning the amount of biomass used. For that reason only estimates can be made. It can be assumed that the efficiencies of biomass used in domestic heating are rather small.

For the future improvements can be made especially with regard to efficiency but also with regard to air pollution. Less polluting fuels could be used and cogeneration systems on a bigger scale could improve the efficiency.

4.2.2 Hydropower:

The potential of Small Hydropower Plants (SHPPs) is estimated at about 0,15 Mtoe, which is a relatively small share compared to biomass. The big advantage of hydropower is that it produces very clean electricity.

Currently in the whole state of Serbia about 50 Power plants are built, of which only 10 are in function. In existing SHPPs the technology is rather old and for that reason the efficiency is rather low. An important increase of efficiency could be obtained by a modernisation of these power plants, if best available technology would be applied.

4.2.3 Geothermal:

The estimated potential of existing sources of geothermal energy is about 0,18 Mtoe which is mainly good researched . There are more than 50 sources with a capacity larger than 1MW. Generally these sources are of low temperature (30-60°C), only few have temperatures higher than 80 °C. Currently geothermal is very weakly used in the energy sector; the biggest use is up to now in spas.

4.2.4 Wind Energy:

The estimations for wind energy are data from meteorological stations which have been measured for one hour on the level of 10 m above ground level. New data are currently gained by research that is financed by the Spanish Government which is measuring the potential on 10, 30 and 50 meters above ground level. With the old data a potential of about 0,2 Mtoe was estimated – which is probably too small, since the masts of modern wind turbines are generally 50 meters high. Some models even have a height of up to 125 meters (Brauner, 2009).

Currently Serbia has no wind power generator installed. This could however soon change since Austrian investors are interested in creating wind parks in the North of Serbia, since this region has an especially high potential in wind energy – 30 % above the European mean value (WKO, 2008).

4.2.5 Solar Energy:

The annual potential at horizontal surface is estimated at about 0,1 toe/m² which is well above the European mean. The main obstacles to the use of photovoltaic are due to economic and technological reasons. The temporal availability of solar energy does not correspond to the demand of energy. That means solar energy would need to be stored. There are few regions where electricity could be stored for example in hydrologic storage power plants. Another, and probably the main reason is the fact that the technology of photovoltaic is still very expensive. Only with appropriate subventions and promotions from the state such investment would be economically feasible at the moment. Currently Solar Energy is only used in the small scale by individual, domestic users for heating purposes like Solar Heating. (Kragic, 2008)

Since Serbia is a continental country without an access to the sea, tidal power is not mentioned in this overview of Renewable Energies in Serbia. In the following part of the thesis biomass will be examined more closely. It is the source of Renewable Energy with the highest potential.

4.3 Potentials of Biomass in Serbia

With regard to the case study chosen, a soy processing company in Vojvodina that is using straw for steam production, in this chapter the potentials of biomass for energetic purposes will be examined and described in a specific way.

Biomass according to the EU directive 2001/77/EC is defined as the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste (European Communities, 2001). As a consequence the following fractions are not to be considered as biomass: mixed municipal solid waste, sewage sludge, textile, paper, cardboard, and waste wood that contains above a certain value toxic components added during wood processing. For the assessment of the potentials of Biomass Energy in Serbia done in collaboration by the Serbian Energy Efficiency Agency, the Vinca Laboratory for Energy, both situated in Belgrade and the Faculty of Technical Sciences in Novi Sad, this definition was the basic approach. The three institutions, in the leadership of Mladen Ilic, Borislav Grubor and Milos Tesic published their findings under the title "The State of Biomass Energy in Serbia" in the year 2004 in the "Journal Thermal Science". For the following part of the thesis this paper served as an important source of information.

Within the national territory of Serbia potentials of Energy from Biomass are to be found in two main sectors: agriculture and forestry. Agricultural production and agriculturally related industries are first of all located in the northern part of Serbia, the province of Vojvodina and in territories along river Sava and Danube, all flat and pure agricultural areas. As source for Biomass for energetic use mainly wastes of crop farming need to be mentioned as well as liquid manure from livestock breeding. Industrial crops rape seed as such have a high potential for energetic purposes. They could be sown in a targeted manner for the production of bio-diesel. Already now rape seed is cultivated in Serbia at an area of around 1.400 hectares. This area could, according to some estimation, be extended to up to 150.000 hectares. With the yield of this area approximately 100.000 tons of bio-diesel could be produced. Compared to the national demand of oil in the transport sector of 1,7 Million tons this amount of bio-diesel is a share of only 6 %.
Apart from crop production and livestock breeding, fruit growing, which is mainly practiced in the hilly region of the south, represents a potential of biomass from agriculture. Hereby wastes from fruit trees like plums, apples, cherries, peaches and grapes need to be mentioned. Serbia's total surface of 88.361 km² is by about 30 % covered with forest – 55 % is considered as arable land. Forest is mainly located in the south of Serbia and it is by two thirds owned by the state, one third by private persons. Half of Serbia's forests are pure deciduous forests, 5 % pure coniferous tree forests, the rest – 45% – are forests with mixed deciduous and coniferous trees.

4.3.1 Agricultural biomass wastes

According to statistical data about agriculture the total area of Serbia used for agricultural production has been decreasing over the last ten years. At the same time the yield per hectare has not increased, for some species of crops it has even decreased. However a differentiation needs to be made with this respect between corn and grapes production and agricultural products whose residues are relevant as energy source. For the first group production went down by 20 % over the last ten years whereas for the second group, relevant for this discussion, production went down by only 10 % (Federal Statistical Office, 2001). Figure 7 shows the agricultural area of Serbia that is used for crop farming and plum production (as an example for fruit growing). As mentioned before one can clearly see that crop production is mainly found in the northern part of Serbia, the province of Vojvodina, whereas fruit (plum) cultivation is mainly practiced in the hilly southern region of Serbia.
In the next part of the thesis the three main groups of biomass coming from agricultural production will be examined more closely: crop farming, fruit growing and livestock breeding.

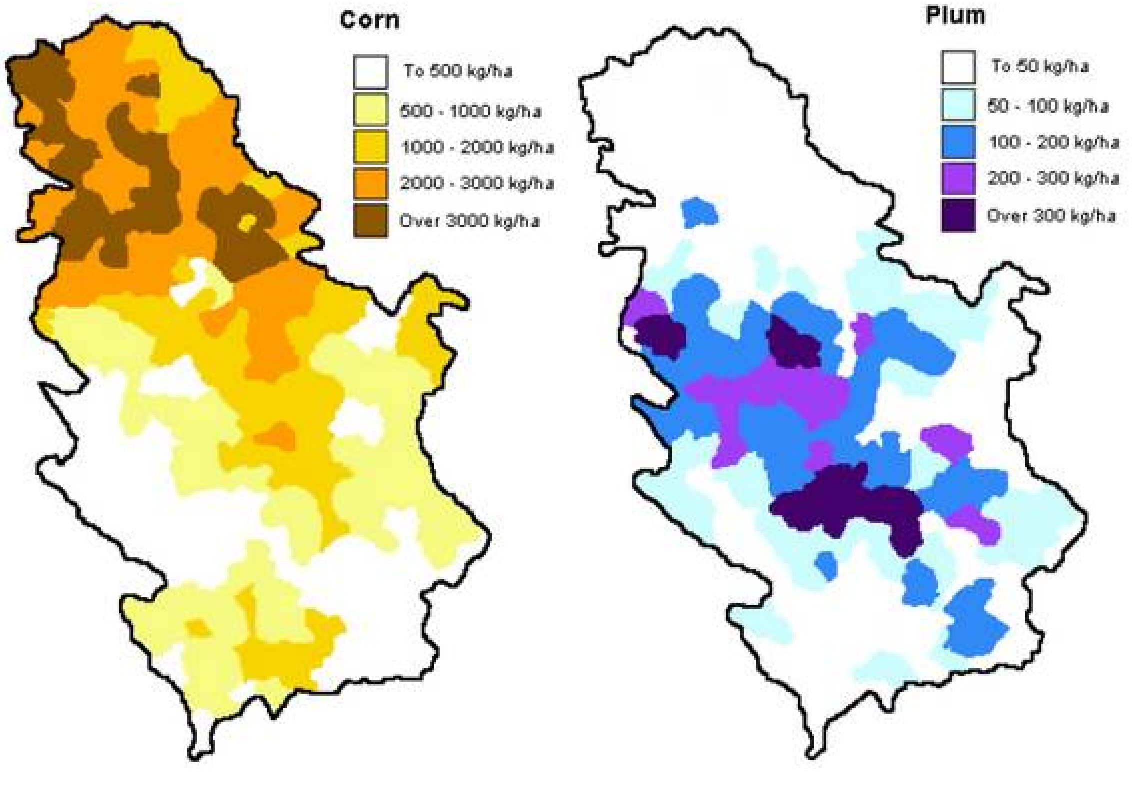

Figure 7 Agricultural area of Serbia used for corn and plum production (Source: Novakovic and Djevic, 2002)

Residues coming from crop farming:

Three quarter of Serbian crop farming is done in small structure agricultural productions by individual land owners whereas one quarter of crops are produced in agricultural companies of relatively large size. These two agricultural structures have very different habits in what concerns the use of residues from crop production. In small structured agriculture which at the same time is breeding livestock, residuals are used for this very purpose. All other small farmers without cattle normally have no other use for biomass residuals and are as a consequence burning the residuals like straw directly on the field. This practice is not only a waste of energy it is also a source of particulate matter. In bigger agricultural productions residuals are very rarely used for livestock breeding. At the same time it is more efficient to collect biomass from bigger entities than from small fields. On bigger fields straw for example can be collected by big specialized machines which directly form bales that can be easily and effectively transported.

Taking into account these considerations, about 50 % of biomass residues from large agricultural farms can be used for energy purposes, while for only 20 % of biomass residues coming from small private farms it is possible and feasible to use them for energetic purposes. The latter share could be increased if small farmers would be equipped with stoves which can use biomass at the small level or if a collecting system for biomass residues for the small scale production could be created that would be economically feasible.

Table 1 shows the values of biomass residues from crop farming for different species and their total energy potential.

Table 1 Yield of the main species in crop farming and the energy potential of their residues (Source: Ilic et al, 2004)

Plant	Area (thousand hectares)	Yield (thousand tons)	grain / residue	Total Residues (thousand tons)	Residues for energy use (thousand tons)	Energy potential (toe)*
Wheat	797.	2 905.	1 / 1	2 905.	1 365.	Average heating value 14 MJ/kg
Barley	135.	365.	1 / 0.8	295.	180.	
Rye	8.5	14.1	1 / 1.1	15.5	4.4	
Corn	1 358.	4827.	1 / 1.1	5 310.	1 140.	
Sunflower	160.	280.	1 / 2.5	705.	240.	
Soya	83.	160.	1 / 2	320.	130.	
Rape seed	1.4	2.6	1 / 3	7.8	1.6	
Total				9 560.	3 060.	**1 023 000. toe**

*(1 toe – ton of oil equivalent = 41 860 MJ)

Table 1 also provides the data for soy beans, the source of biomass for Sojaprotein, the company examined in the case study. Out of the 320.000 tons of total residuals from soy bean production, less than one half, 130.000 tons can be used for energetic purposes.
In total, taking into account all species, 3 Mio tons of residuals could be used for energy production. If one estimates that the average heating value of residuals from all different species is about 14 MJ/kg, a total Energy Potential of 1.023.000 Mtoe can be calculated. This amount of energy could replace fossil fuels in Serbia's Total Primary Energy Supply (TPES) of 17,07 Mtoe (International Energy Agency, 2008-1).

Residues coming from fruit growing and viniculture:

From fruit growing and viniculture three main fractions can potentially serve as a bio fuel: small branches of trees and grape-wine; peels, seeds and stones of different fruits; and old trees and grape wine that are replaced by new ones.

Table 2 Energy potential of biomass residues deriving from fruit cultivation and processing (Source: Ilic, 2004)

Species	Number of trees (thousands)	Fruit production (ton/year)	Type of biomass residues	Biomass residues (ton)	Annual energy equivalent (toe)
Plum	50 630.	382 400.	pruning, stones	393 500.	132 600.
Apple	17 570.	198 400.	pruning, peel	36 200.	10 900.
Cherries	12 280.	99 500.	pruning, stones	55 000.	16 500.
Pear	7 080.	70 000.	pruning, peel	14 000.	4 300.
Peach	4 450.	44 400.	pruning, stones	35 100.	11 700.
Apricot	1 900.	27 500.	pruning, stones	15 500.	4 100.
Walnuts	2 100.	21 500.	pruning, shell	55 000.	14 100.
Grape	77 390 hectares	213 000.	pruning, peel, seeds	515 000.	166 300.
				Total (toe):	**360 500.**

Table 2 shows the energy potential of biomass residues deriving from fruit cultivation and processing. The biggest potential in terms of annual energy equivalent in Serbia represents grape production with 166.300 toe, followed by plum production with 132.000 toe. These two fields of agricultural production also represent the biggest share in fruit production in absolute terms. Less potential is represented in the residuals that emerge in the cultivation of cherries, walnuts, peaches, apples, pears and apricots. The potentials of the latter mentioned species range between 4.000 and 14.000 toe. In sum the potentials of all different species used in fruit production and viniculture account for approximately 360.500 toe.

In viniculture and fruit growing small branches are residuals which are produced by pruning. The total number of registered fruit trees in Serbia is about 94 Million out of which half are plum trees, 20 % apple trees and 15 % cherry trees. The rest are pear, peach, apricot and walnut trees. One can estimate the annual quantity of branch residuals per tree between 1 kg and 7 kg. In viniculture about 4 to 8 tons of branches can be estimated per hectare. In total these estimations would account for 475.000 tons of branches per year. Supposing an average heating value of approximately 14 MJ/kg one can calculate an annual energy potential of fruit tree and vine pruning residues of about 314.000 toe. Together with the potentials of peals, seeds and cores the above mentioned sum can be estimated. For peals however the potential is not quite clear, due to the relatively high water content.

Fruit trees and grape-vines need to be replaced every 10 to 25 years. Due to this fact one can estimate the annual potential for energy from old trees and vines (inclusive their roots) at about 245.000 toe.
To sum up and taking into account all above mentioned figures: the overall energy potential of biomass residues from fruit growing and viniculture can be estimated at approximately 605.000 toe.

Biomass wastes coming from animal origin (livestock breeding):

Biomass wastes are produced in livestock breeding of cattle, pig, poultry and sheep. The manures of these animals normally contain a rather high amount of water. For that reason anaerobic digestion is suggested. Apart from the biogas that can be gained in this way one obtains a very valuable, environmentally friendly fertilizer. According to the Serbian Statistical Office (2001) the amount of livestock breeding went back quite drastically over the last 15 years. In large agricultural farms the decline was very steep: cattle breeding decreased by 40 %, pigs breeding by 20 % and poultry breeding by 60 %.
However the major part of livestock breeding is located in small farms, meaning farms with only a few heads in each. In these small structured conditions a collection of manure for centralized anaerobic fermentation is technically and financially not feasible. For that reason, rather farms of larger size represent a potential for energy production. Manure from these farms does not need to be transported and can be anaerobically treated directly at the place of production.

Table 3 shows the state of main species of livestock in medium and great farms:

Table 3 Livestock in medium and great farms and energy potential of their manure (Source: Ilic et al, 2004)

Livestock	Location of farms	Number of heads	Manure (m^3/day)	Biogas (m^3/day)	Annual Energy Equivalent (toe)*
Cattle	Flat regions	149 300.			
	Hilly regions	111 000.			
	total	260 300.	5 270.	105 000.	20 140.
Pigs	Flat regions	1 369 500.			
	Hilly regions	285 600.			
	total	1 655 100.	4 560.	91 200.	17 500.
Poultry		2.35 million	480.	24 000.	4 600.
					Total **42 240**

*(1 toe – ton of oil equivalent = 41 860 MJ)

In Serbia there are about 260.000 cattle, 1,66 Million pigs and 2,35 Million poultry, producing the above shown amounts of manure. With this amount, by anaerobic fermentation, 220.200 m^3 of Biogas can be produced daily, representing a total Annual Energy Equivalent of 42.240 toe.

4.3.2 Biomass Wastes from Forestry

In figure 8, which represents the share of forest area in the total area of communities in Serbia, one can clearly see that the biggest part of Serbia's wood stock is located in its hilly southern part. There are communities with a share of more than 45 % of their area covered by forest.

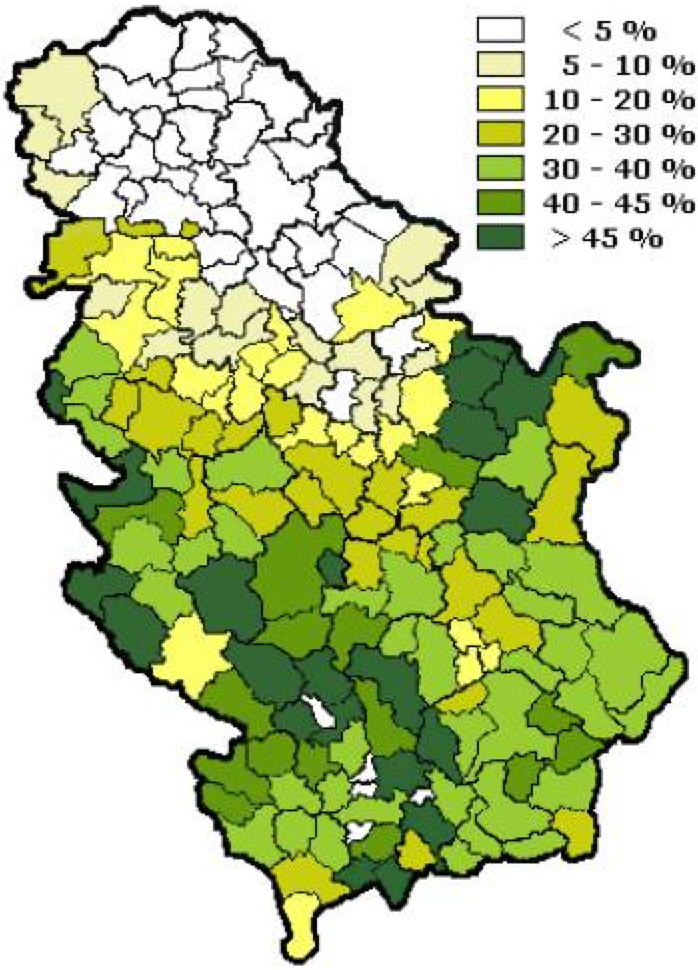

Figure 8 Share of forest area in the total area of communities in Serbia (Source: Federal Statistical Office, 2001)

Total wood stock in Serbia is approximately 235 million m^2. Apart from registered wood felling which accounts for about 2,9 mill m^3, unregistered felling is estimated at about 0,4 mill m^3. The assumed 3.3 mill m^3 of total annual wood felling however only represent 55 % of the annual increase of wood-stock in forests of about 6,1 mill m^3. This figure can be compared with the figures from developed countries where forest management is sometimes better organized. In some "western states" the ratio between wood felling and annual stock increase is 75 %. That means, the potential of biomass from forestry can be considerably increased by

an improvement in forest management. Another fact that is likely to increase the potential: the share of total state territory covered by forest is estimated and promoted to increase from the current 30 % up to almost 42 % until the year 2050.
At present the estimated annual energy potential of different kinds of wood residues, together with registered consumption of fuel wood accounts for about 1.2 Mtoe. For the future this amount could not only be increased by the above mentioned measures and improvements but also by cultivation of energy plantations. The annual energy potential of forest energy crops accounts for some 382.000 toe (Ilic et al, 2004).

The facts and figures of this chapter give evidence that Serbia has a high potential in Renewable Energies and particularly in Biomass. This fact is sum up in the Table 4. It describes and quantifies the different sources of Biomass available in the national territory of Serbia. The sum of potentials of all sectors potentially producing biomass account for 2,6 Mtoe.

Table 4 Potentials of Biomass in Serbia according to sectors (source: author)

Sector	Potentials [toe]
Agriculture Crop Farming	1.023.000
Agriculture Fruit Cultivation	360.500
Agriculture Livestock	42.000
Forestry	1.200.000
All sectors	**2.625.500**

4.4 Biomass and Bioenergy at a global level

In order to expand the scope of view, in the following chapter Biomass will be examined at a global level. Trends and figures are given in order to emphasise the importance of Biomass in total world energy supply and to show its potentials for the future. In a second step the most important conversion technologies are described.

4.4.1 Trends and figures

Biomass, which is grown organic material that is collected or harvested for energy use, is a source of renewable hydrocarbons that can be converted into energy. The results of the conversion process are energy carriers, such as heat electricity and transport fuels; moreover materials and chemicals can be produced. Conversion products made from biomass generally are named with the prefix “bio” like for example Bioenergy, Biofuels, and Biogas, biomaterials or bio-chemicals.

Over the recent years the total annual demand for biomass has steadily increased as one can derive from figure 9. This rise was especially strong in OECD countries. Whereas in the year 1970 Global Primary Biomass use was about 600 Mtoe, today it accounts for about 1200 Mtoe – it doubled over the last 40 years. This rise is likely to increase during the years to come due to a higher demand in renewable energies in general.

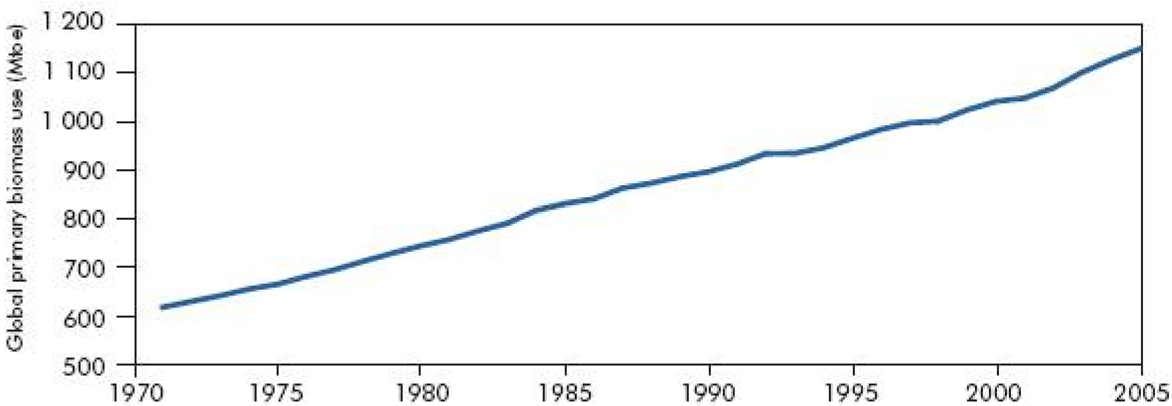

Figure 9 Global primary biomass use from 1970 to 2005 (Source: IEA, 2008-2)

The share of biomass in total primary energy consumption can only be estimated. Currently it probably accounts for about 10 % - in absolute terms about 1070 Mtoe/y with an uncertainty of +/- 240 Mtoe/y. Two thirds of global biomass consumption as primary energy source take place in developing countries as traditional, non commercial biomass, like fuel wood, crop residues or dung, for domestic cooking and heating – in a very inefficient way. One third only is consumed in developed countries – generally in a more efficient way. For the production of electricity and heat for buildings, biomass is currently used to the extent of 190 Mtoe per year and in the transport sector as liquid Biofuels to the extent of 40 Mtoe (IEA, 2008-2).

As it was already mentioned above, biomass is used on the small scale and on the large scale. Use on the large scale in general is done in a more efficient way than on the small, domestic scale. There biomass is used for cooking and heating in households in most parts of the world. In some developing countries the dependency on traditional biomass is up to 90 %. Especially in those countries and regions the efficiency of use of biomass could be significantly increased by the introduction of better, more modern designs for stoves and ovens. In that way the amount of biomass needed to provide the same energy services could be reduced drastically and at the same time air emissions would be reduced. As a consequence the health conditions of the users would be improved by avoiding carbon-monoxide inhalation. The overall efficiency of small-scale biomass use is expected to increase through to the year 2050 (IEA, 2008-2) for several reasons: fewer people are expected to live in rural areas, more people will live in urban areas equipped with facilities of higher energy efficiency. Overall an uptake of more efficient stoves is expected as well as a spread of small-scale biogas systems and biomass-based liquid cooking.

Biomass is used at a larger scale to provide heat in buildings and in the industry. In 2005, according to the International Energy Agency, biomass and waste contributed about 105 Mtoe, which is a share of 1,4 % in total direct heat in global industrial and residential sectors (IEA, 2007-1). Approximately additional 47 to 70 Mtoe have been provided by CHP plants. With regard to transport, biomass has provided 1% of transport fuels which corresponds 19 Mtoe. Moreover biomass is estimated to having provided more than 1 % of global electricity generation (IEA, 2007-2).

With regard to future estimates: the predictions vary widely. Biomass is very likely to make a significantly larger contribution to primary energy in the next 30 to 40 years. This development is subject to sustainable production, improved efficiency in the supply chain, the successful development and deployment of new thermo-chemical technologies, and improved bio-chemical conversions like for example anaerobic digestion, and ethanol fermentation. Liquid Biofuels or other energy sources are expected to replace traditional solid biomass at least partly as people are progressively moving from the rural regions into urban areas. Development in rural areas of developing countries could be driven by facilities like improved cooking stove designs, community biogas plants, Stirling engines for Combined Heat and Power Plants and an overall increase in the size of heat plants (IEA, 2008-2). In that way the overall conversion efficiency is very likely to increase at a global level during the next decades.

To sum up: Bioenergy currently represents the largest renewable energy contributor to global primary energy; it has the highest technical potential of all renewable energy sources. At the same time biomass is rather used inefficiently in a wide range in traditional domestic cooking and space heating which accounts for around two-thirds of total current demand. Efficiency is estimated to increase until 2050 by a transition towards a more efficient use and improved conversion technologies such as liquid bio fuels. By 2050 the amount of biomass available from residues and energy crops will be dependent on the efficiency of the world agricultural and forestry systems. In heat and power applications and the production of bio-chemicals, bio-fuels and other bio-materials sustainably produced biomass is expected to be of a high demand in 2050.

4.4.2 Biomass conversion technologies

Worldwide, around 400 GW of modern biomass heat-production equipment is currently consuming around 300 Mt of biomass per year. With this amount of biomass about 4,5 EJ, which equals 105 Mtoe, of direct heat can be produced yearly if one assumes a conversion factor of 75%. Over 40 GW of biomass-fired power generation capacity had been installed in the year 2005, generating 230 TWh of electricity per year. If one assumes a 60 % average capacity factor and a 25 % average conversion efficiency factor, about 240 Mt of biomass resources would be consumed per year. With regard to Biofuels, around 120 Mt of biomass resources were consumed in 2005. With this amount of biomass resources around 19 Mtoe of Biofuels were produced, implying an average conversion efficiency of around 50 % (IEA, 2008-2)

Today several well established technologies for the conversion of Biomass into Primary Energy are in use. One can distinguish on the large scale between those categories of technology:

- Power generation: combustion
- Power generation: gasification
- Combined heat and power (CHP)
- Biofuels for transport

These technologies are listed for reasons of completeness. As in the case study chosen in Serbia biomass is combusted, in the following chapter combustion technology is described and examined more closely.

Power generation – combustion:

With regard to combustion technologies one can distinguish between traditional grate boilers which are in general used for rather small applications, bubbling (BFB) and circulating (CFB) fluidised bed combustion and finally co-firing of biomass in utility boilers.

Grate Boilers are based on the oldest and most simple principle of combustion; it was the most common design of small-size boilers (less than 5 MW) until the beginning of the 1980ies. In these relatively small facilities, there is rarely a grate boiler installed in a plant over a capacity of 50 MW. Wood pellets, straw, plywood, chipboard residues and municipal waste are used as fuel. Design and location are the main cost factor of such an installation. Moreover it could be clearly shown that there is a close relationship between plant size and investment cost. As plant size increases, costs per unit of installed electricity-generation capacity dropped quickly VTT, 2007). Figure 10 shows the correlation between capacity of an installation and investment costs per unit of capacity for different combustion technologies, grate boiler, BFB and CFB. The two latter ones will be described below. One can see the benefit of plants with larger capacities from economies of scale.

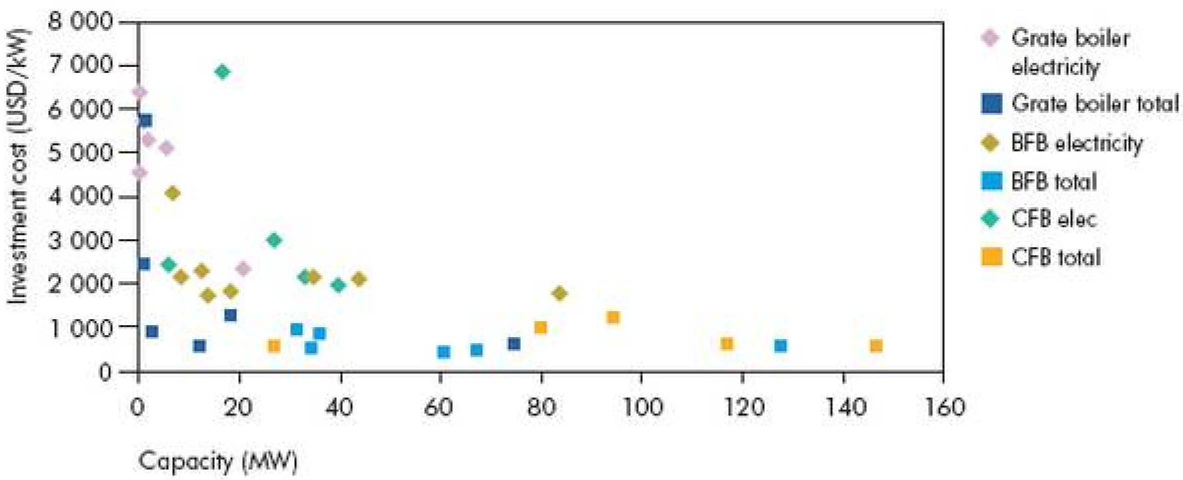

Figure 10 Relation between specific investment costs and total heat and power output capacity of grate boilers and fluidised beds. (Source: VTT, 2007)

Fluidised Bed Combustion became wildly spread by commercialisation in the 1970ies. One has to distinguish between bubbling fluidised bed combustion (BFB) and circulating fluidised bed combustion (CFB). The first technology resembles grate firing, it offers however better temperature control and is more suitable for non-homogenous biomass. The second technology just mentioned resembles pulverised fuel combustion. A better control of furnace temperature however allows the fuel to be ignited without necessitating a high temperature flame. The difference between CFB and BFB technology is that in BFB boilers the bed particles stay in the bed whereas in CFB boilers the gases carry the particles away from the bed into the furnace. From the furnace they are later circulated back into the bed. Figure 11 shows an example of a multi fuel, circulating fluidised boiler. The mixing of air and fuel is improved by the bed material in the combustion system; heat transfer is improved as a consequence. One aspect of this technology is its complexity, at the same time it is scaleable to gain greater benefit of size. This advantage is however partly offset by the higher costs of transporting biomass fuel over greater distances.

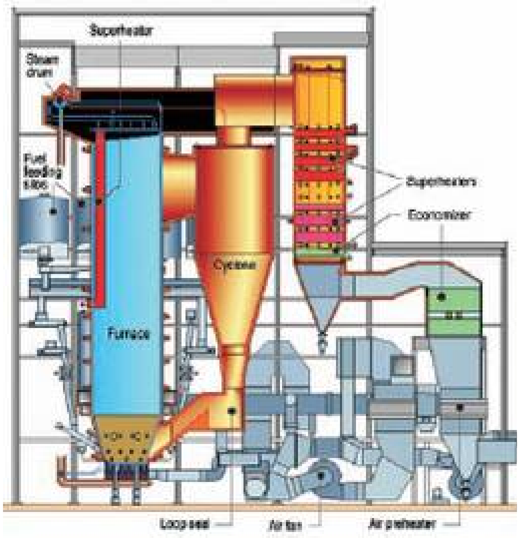

Figure 11 Example of a multi-fuel, circulating fluidised bed boiler (Source: VTT, 2007)

Fuel type, ash content and quality and the amount of physical impurities determines whether grate or fluidised bed firing is the better choice. Fuels with a low ash melting point are not appropriate for fluidised bed technology. New, advanced technologies and solutions for keeping the bed operational with municipal solid waste for example have nevertheless been developed and implemented successfully.

Another application of biomass combustion is co-firing in traditional utility boilers for electricity production. This application can make quite a big difference in terms of CO2 emissions. In more than 150 installations worldwide this technology has been successfully implemented and demonstrated in many different combinations boiler types and fuels, including crop residues, energy crops and herbaceous and woody biomass. Generally the proportion of biomass in the fuel mix is between 0,5 % and 10 % in energy terms. Several advantages of co-firing can be listed:

- CO2 emissions are reduced;
- Existing infrastructure is used more effectively;
- Investment costs are lower than those for new biomass boilers;
- Energy-conversion efficiency is higher than the one that could be obtained in smaller scale biomass facilities;

- Risks associated with biomass supplies can be reduced; storage areas can be kept smaller;
- Flexibility to purchase fuels according to their changing price levels increases;
- Sulphur and nitrogen-oxide emissions are reduced (IEA, 2008-2)

In general energy efficiency of biomass is only 10 % lower than the one of coal. This implies a decrease of energy efficiency of 1 % in co-firing if for example 10 % of biomass is added to coal.

5 Case Study Sojaprotein

Industrial Processes account for a considerable share of GHG emissions worldwide. Although energy efficiency has increased during recent years, emissions are steady increasing. Industry however is a sector in which fossil fuels can be substituted by renewables energies in an effective manner.

This case study is aiming to give a example where such a substitution has already been successfully implanted. By the investment in a new boiler fuelled by residuals from agricultural production, Sojaprotein was not only able to reduce the company's emissions of carbon dioxide triggering climate change; the investment brought a considerable economic benefit already in the past and one can assume that the benefit will be even higher in the future, especially as prices for fossil fuels are expected to increase.

This case study should moreover serve as a kind of model and incentive for industries in other transition economies to design their own concept for the use of renewable energies.

5.1 Company-profile

The company Sojaprotein in Becej is situated in the North of Serbia in the region called Vojvodina, a very fertile region in which agriculture is the biggest economic factor. Becej, a town with 24.000 inhabitants, is located about 50 km northeast of Novi Sad, the capital of the province of Vojvodina. Figure 12 shows a map of Northern Serbia and the exact location of Becej. In figure 13 which represents a map of the municipality of Becej, one can see the precise location of the company Sojaprotein. The factory is located in the closest vicinity of the Danube-Tisa-Danube Canal, at a location where the Canal joins the river Tisa; the company is connected with international water ways. Apart from water ways, the company is also connected with the European road and railroad system enabling the use of all different means of transport.

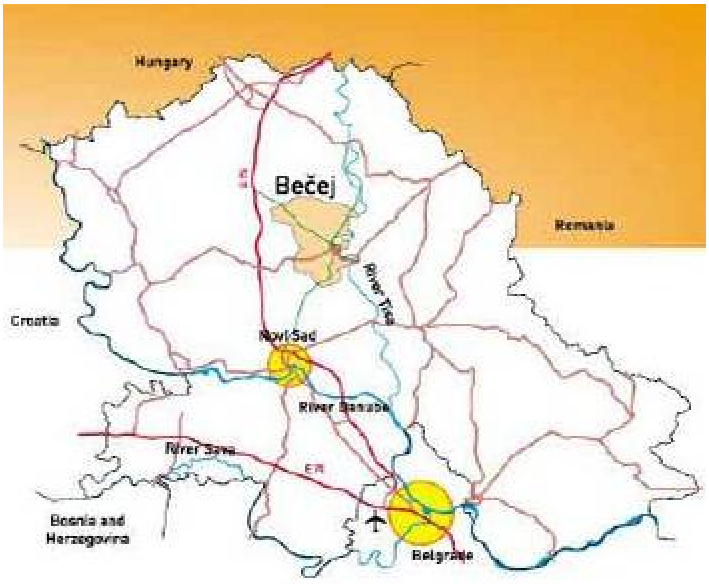

Figure 12 Map of Central and Northern Serbia with Becej (Source: Sojaprotein, 2008)

Sojaprotein is processing 80 % of Serbia's harvest of soybeans. It is the only company of this kind in Serbia and the most significant one in south-eastern Europe. The company was established during the time of communism in the year 1978 and started with regular production in the year 1982. After the fall of communism, the company was privatised in 2001 and is now a joint stock company with the Serbian Victoria Group, located in Sabac (Serbia), as main stock holder. Shares of Sojaprotein are traded at the Belgrade Stock exchange and they are open for transactions. The Company holds majority share of the company SP Laboratory in Backa Palanka Port at the Danube and the Mladost Vegetable Oil Production in Sid. Sojaprotein AD has the majority share at ZAO Vobex Intersoya, Moscow, a trade company distributing their products on the Russian market. The processing capacity is according to information given on the website 900 tons of soybeans per day (Sojaprotein, 2007) which is about 300.000 tons yearly. The origin of the soybeans is 100 % Serbian. The company supports agricultural companies and farms by loans for the soy production. By doing so it can guarantee that it processes soybeans that are without any exception not genetically modified. All products are certified for being GMO free.

Figure 13 Map of Becej that indicates the precise location of Sojaprotein (Source: Sojaprotein 2008)

The customers of Sojaprotein are the food and the feed industries. The company's most important products in the order of decreasing quantities are: Soy Grit, Soy Oil, Textured Soy Protein Products, Soy flours, Extruded Fish Food, Hull, Special Grits, Crude Soy Lecithin, Functional products for the Food Industry and finally the Soy Vita Program, which is a product line directly distributed. Due to their high quality oil and protein, soybeans and their products have a high nutritional value.

5.2 Production Process Sojaprotein

The first step of the company's process is the reception of the harvested soy beans. In general the soy beans are delivered by trucks. After reception the soybeans are passed through a process of cleaning and drying. In the cleaning process impurities and debris from the harvested crops are eliminated. Drying is normally done to a level of moisture of about 9,5 per cent. After cleaning and drying the hulls of soybeans are removed by aspiration before they are stored in huge silos.

Soybean hulls account for about 8 % of the soybean; later they are used as a fuel in the combustion process of the steam boiler. Soybeans without hulls are known as meats. Several advantages for removing the hull can be stated: a smaller total volume resulting in a higher density in the following processes. As a consequence the extraction output per day is bigger and the protein content of the meal is higher.

Soybeans are cracked into 8 to16 pieces in the cracking-process. The cracked soybean meal is heated up in order to be softened before flaking. Soybean meal needs to be properly cracked and conditioned, in order to achieve the desired cell rupture and distortion required for an effective process of extraction. Like that the production of excessive, fine material that interferes with effective extraction is avoided. Highly distorted cells in general extract more easily however. Heated and cracked meat is processed into very fine flakes. These flakes are then conveyed by an expander which produces a porous pellet with increased cell rupture and greater density. The advantage of using expander equipment is that oil can be more easily extracted from the flakes, the solvent drains more completely. As a consequence the amount of solvent that needs to be evaporated from the meal is considerably reduced and the through-put capacity of the extractor is increased.

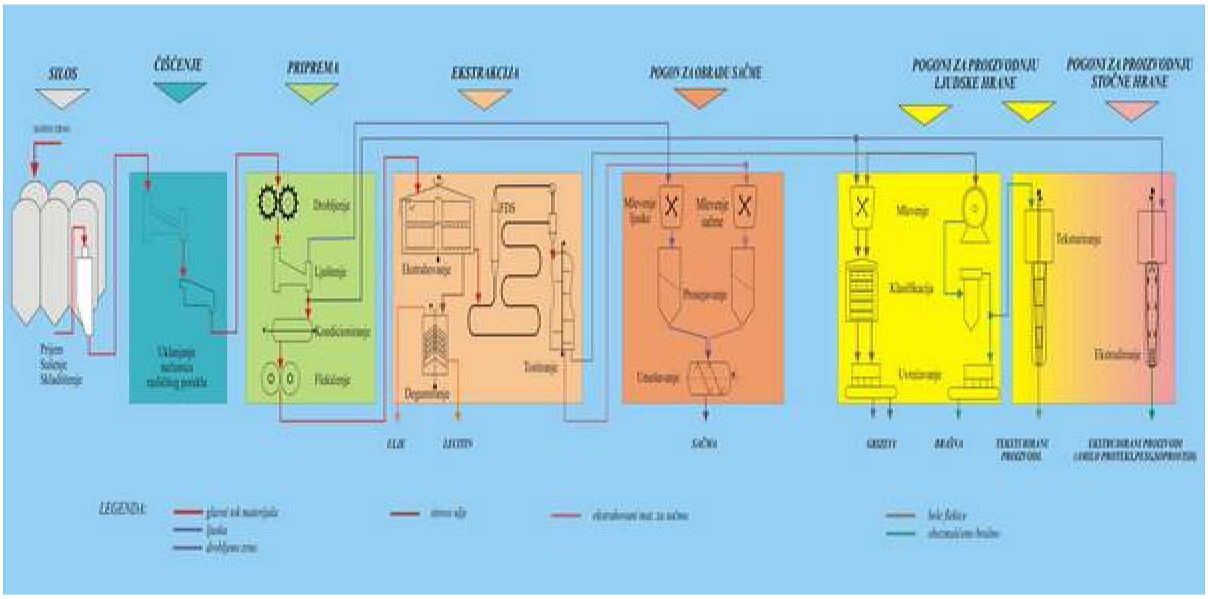

Figure 14 Process Flow diagram of the production line of Sojaprotein (Source: Sojaprotein, 2008)

The next step in the production process is extraction. The extractor operates by a process involving percolation of the solvent through a bed of flakes. The flakes are washed in a counter current manner with hexane, a distillate of mineral oil. This solvent solves the lipid material of the soybean. Through a series of steps the hexane-oil mixture is separated. The oil-rich extract called “miscella” is evaporated and the solvent is reused in the extractor. Soybean flakes where oil has been removed are called “spent flakes”. From the extractor, spent flakes are conveyed to a toaster for the removal of the solvent hexane that still might be contained by the flakes. The process involves the heating of the spent flakes in order to evaporate the hexane; hexane vapours are carried away. The same process provides for toasting of the meal to inactivate enzymes like urease and trypsin inhibitors which might reduce the digestibility and the nutritional value of the meal.

From the toaster the meal goes to a dryer-cooler where the meal is dried to about 13-14 % of moisture and cooled for save storage. The meal is then screened and ground with a hammer mill to produce a uniform particle size (flour, grit). This is one of the final products which are transported to the consumer. The finished meal from soybeans without hulls contains less than 1,5 % crude fat and about 48 % proteins. It is classified as high protein meal.

Figure 14 shows the Process Flow Diagram of the production line of Sojaprotein. As described above it visualises the different stages of processing necessary for the production.

5.3 Steam Production

One process that is essential for many industries, not only in the ones dealing with food processing, is steam production. Steam can be considered as an energy carrier which requires primary energy to be produced. Fossil fuels are the main primary energy for the steam production. Nowadays more and more facilities are using renewable energies like solar energy or biomass. Steam is used in the paper production as well as in diaries and many other applications.
Since steam is applied in many different ways and for many different industrial processes, it has a kind of exemplary, general character. Examining steam production of a special company of a specific sector makes it possible to compare the industrial processes of companies of different sectors, processing different materials and producing different products.

For the production process of Sojaprotein steam is one essential component. In the year 2007 the company consumed 100.605 tons of steam which was produced by natural gas as primary energy (Sojaprotein, 2008). That means Sojaprotein is a big energy consumer. Apart from gas the company consumed electrical energy, petroleum, diesel and bio diesel for its energy supply.

As just mentioned, until the year 2008 energy supply for steam production was exclusively provided by fossil fuels: Natural Gas for normal operation and mineral oil for emergency operation. The company participated in UNIDO's Project "Cleaner Production 2008-1" organised by the Cleaner Production Centre of Serbia (Belgrade) in the year 2008. After the assessment done by national experts, the company decided to invest in a new boiler house that would be run by renewable energies. Three main reasons are stated by Sojaprotein for the decision of the investment: savings in the cost of fuel; reduction of dependence on other energy sources; commitment to sustainable development and to an Environmental Management System (EMS).

Apart from the boiler house a storage capacity for the soy-straw-bales was required; an area of 31.350 m² which equals 3,1 hectares was established. During the year 2009 a filter house for the off gases will be built. A fist experimental use of the boiler with a capacity of 15t steam per hour started in November 2007; use on a full scale started in October 2008. As main fuel, soy-straw is used. It is available in big quantities and for a cheap price in the region of Vojvodina. Soy straw is mixed with soy shells which are a residual from the production process of Sojaprotein and sunflower husks which are a waste product of a sunflower oil mill also owned by the Victoria Group. Waste from the elevator, which are impurities from the reception and storage of soybeans (pieces of stalk, dust, other beans than soy and shucks...), is another fuel used. Before the biomass boiler was installed, this material was rejected as waste or sometimes used as raw material for feed.

The installation made Sojaprotein one of the leading companies in using renewable energy resources. The installation, according to the company, was easily achieved. It can be considered as a "low hanging fruit" with economic and environmental benefits.

The total investment is realised in two phases: The first phase was realised in 2007 and 2008 with the construction of the boiler house, the installation of the boiler and the preparatory facilities and the allocation of the storage capacity. A second phase of investment which is related to the installation of filters for off gas purification should be realised in 2009.

5.4 Data of Energy Supply

Table 5 shows the quantities in tons of different fuels with biomass origin which were used in the first three months of 2009 for the production of steam in the Sojaprotein Company of Becej – in total 3.653 tons. Data show that by weight, during the three months observed, sunflowers had the biggest share, followed by soy straw and soy shells. Rather small quantities stem from waste from the elevator.

Table 5 Composition of biomass used as fuel for steam production in the Sojaprotein Company of Becej (Source: Sojaprotein 2008)

Composition of biomass					
Quantities (t)	Sunflower shells	Soya shells	Soya straw	Waste from elevator	
2009					
January	870	0	389	0	
February	484	109	363	17	
March	684	104	538	95	
Total	2.038	213	1.290	112	3.653

These four different fuels, Sunflower shells, Soya Shells, Soya Straw and waste from the elevator have different chemical composition and different heating values. The relevant data are given in Table 6. Maize chaff, for which data are also listed in the table, is not used as a fuel. It was only analysed for reasons of comparison. With regard to moisture soy straw and waste from the elevator have highest content followed by sunflower and soy husks.
With regard to carbon content, the five fuels differ quite considerably, ranging from 26 % for Soy Shell up to 39 % for sunflower shells.

Table 6 Results of chemical analysis of different renewable energy resources and their heating value (Source: Sojaprotein, 2008)

Chemical analyses of biomass					
(%)	Sunflower shells	Soya shells	Soya straw	Waste from elevator	Maize chaff
Moisture	10,03	8,44	15,53	14,41	8,80
Ash	4,96	4,19	3,54	13,54	4,44
Total S	0,32	0,23	0,18	0,30	0,26
Carbon (C)	21,87	15,06	17,98	25,58	17,63
C fix	16,92	10,87	14,44	12,03	13,18
Carbon Total	38,79	25,93	32,42	37,61	30,81
Upper heating value (kJ/kg)	17.898	19.197	15.393	14.883	16.222
Lower heating value (kJ/kg)	16.946	18.281	14.418	13.933	15.298

For a technology that claims to be environmentally sound, waste products, residuals like ashes are of concern. In Table 7 the results of chemical analysis of the ashes of the biomass is shown. The ash contains the also heavy metals Nickel, Mercury and Cadmium.

Table 7 Results of the chemical analysis of the ash of biomass (Source: Soyaprotein, 2008)

Chemical analyses of ash	
Content	(%)
Moisture	60,35
Dry base	39,65
Ash	34,21

Content of Metals	**mg/kg**
Ni	**4,295**
Pb	**1,372**
Cd	**0,062**
Cr	**<0,001**
Mo	**1,141**
As	**0,109**
Hg	**<0,001**
Zn	**11,360**
Sn	**4,431**

With regard to costs, the company claims that choosing biomass as a fuel made it possible to save a considerable amount of financial means. Compared with the first three months of 2008, when the total costs for gas and electricity was about 880.000 Euros, the costs in the first three months of 2009 went down to about 480.000 Euros, which is a reduction of about 50 %. In the cost benefit analysis of a later chapter these numbers will be examined in more detail.

In Table 8 precise figures are given:

Table 8 Quantities and costs for gas, electricity and biomass for the energy supply of "Sojaprotein" for two periods of three months in 2008 and 2009 (Source: Sojaprotein, 2008)

	Quantities I - III 2008.	***Quantities I - III 2009.***	***Costs I - III 2008. (EUR)***	***Costs I - III 2009. (EUR)***
Gas: [m3]	**2.306.138**	**109.307**	**644.118**	**45.804**
Electrical energy: [kWh]	6.218.100	6.569.100	237.590	249.539
Biomass [kg]	0	3.504.349	0	158.815
Soya shells [kg]	0	557.750	0	26.389
Total Biomass [kg]	**0**	**4.062.099**	**0**	**185.204**

One can clearly see that the consumption of electrical energy was more or less stable in the two compared periods. Gas consumption however could be reduced by about 95% by substitution with Biomass.

The quantities and costs for gas and electrical energy for the years 2005-2008 are shown in Table 9. Since the biomass boiler was only installed in the end of 2008 there are no data available for a full year of biomass consumption.

Table 9 Quantities and costs for gas and electrical energy of "Sojaprotein" for the years 2005 – 2008 (Source: Sojaprotein, 2008)

	Quantities	**Conversion factor**	**Energy consumption**	**Costs**
2008			[GJ]	[din]
Gas: [m3]	7.821.644	0,0342	267.500,225	208.771.550
Electrical energy: [kWh]	25.864.140	0,0036	93.110,904	89.126.453
2007				
Gas: [m3]	7.249.086	0,0342	247.918,741	145.168.447
Electrical energy: [kWh]	24.898.680	0,0036	89.635,248	67.975.354
2006				
Gas: [m3]	10.412.213	0,0342	356.097,685	237.324.983
Electrical energy: [kWh]	24.867.840	0,0036	89.524,224	71.323.225
2005				
Gas: [m3]	11.479.001	0,0342	392.581,834	195.776.664
Electrical energy: [kWh]	24.683.560	0,0036	88.860,816	56.881.789

Overall Energy consumption during the last years stayed relatively stable. The amount of electrical energy was more or less stable over the years. From the data of the first three months of 2008 and 2009 it gets clear that biomass is not substituting electrical energy but only gas. For that reason subsequently only the amount of gas and biomass will be considered in the analysis of data that are aiming to examine the Carbon Dioxide balance of the industrial processes of Sojaprotein.

5.5 Material Flow Analysis

For the Material Flow Analysis (MFA), as described in the Methodology, special software provided by the Institute for Water Quality, Resource and Waste Management of the Vienna University of Technology was used. Background information on the theory behind the STAN computer program gives the Practical Handbook of Material Flow Analysis (Brunner and Rechberger, 2004).
With the help of this program the situation before and after the investment into the new boiler house will be described at three levels of flows:

1. Energy
2. Material
3. Carbon

This clear distinction makes further investigation with regard to issues of climate change and scarcity of sources of primary energy possible – moreover it facilitates a cost benefit analysis. First the situation before will be described by taking into consideration the three levels. In a second step the same will be done for the current, new solution involving renewable energies.

5.5.1 Situation before

Until the installation of the new boiler house for the combustion of renewable energies, Sojaprotein used without any exception fossil fuels as source of energy for steam production. Natural Gas at that time was the only source of primary energy used for steam production. It was burned in the gas boiler.

In the MFA, as years of reference, the two years before the first experimental use of the biomass boiler were chosen. For these years all energy was still entirely provided by fossil fuels. Their average numbers were calculated. Before the installation of the new boiler the annual energy consumption was 374.340 GJ. According to information given by Sojaprotein, the fuel-to-steam efficiency of the gas boiler is 85 %. As a consequence 318.189 GJ (85 %) of the total annual energy consumption could be converted into steam, 56.151 GJ (15 %) were lost in the conversion process (see Figure 15).

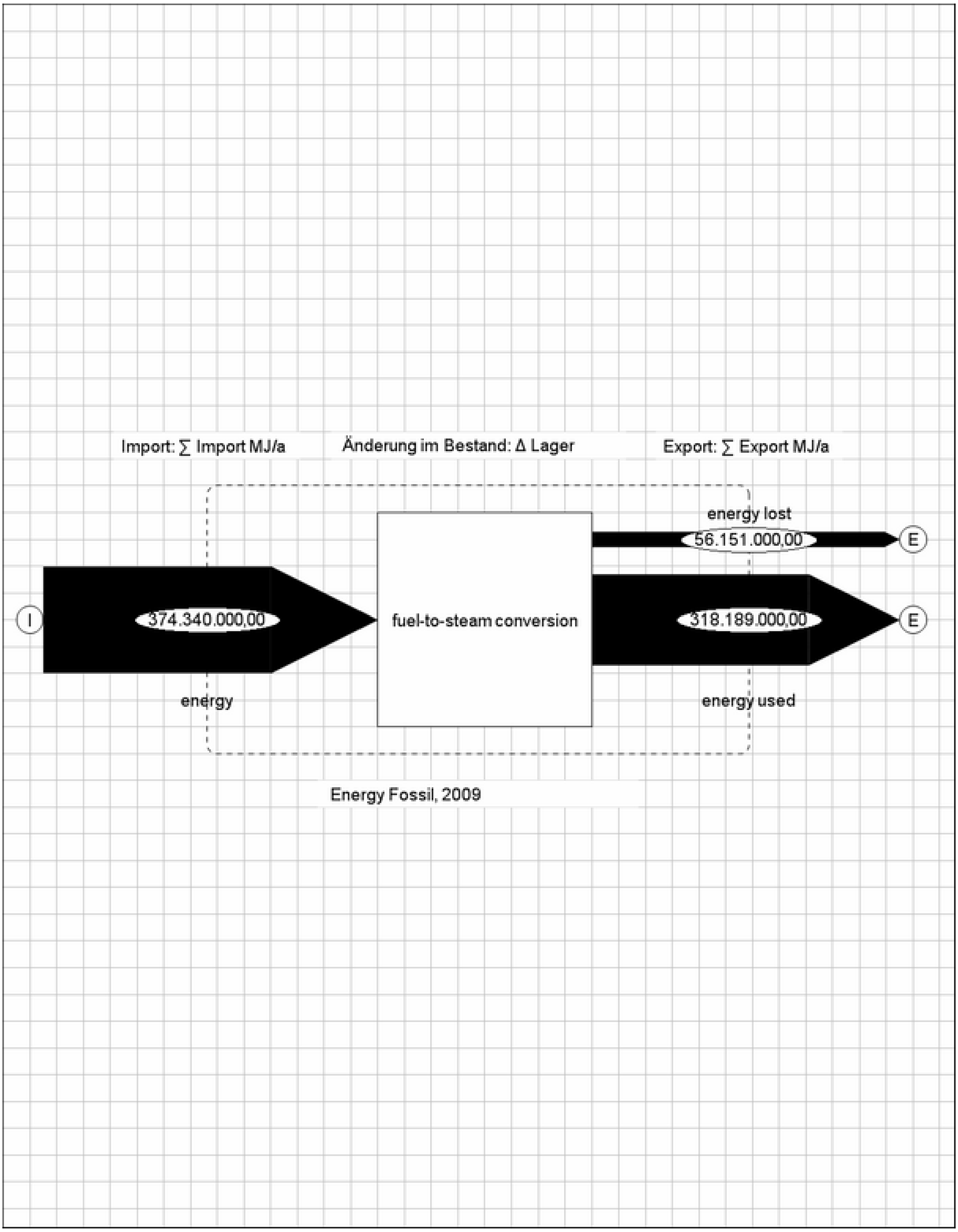

Figure 15 Average annual energy flow for Soyaprotein before investment (source: author)

The annual quantity of gas consumed was 10.945.607 m3, which equals 10.945.607.000 litres. In order to convert this figure into the unit of mass [g] one needs to know the volume of 1 mole of gas, which is 22,4 l and the mass of one mole (molar mass) of methane which can be calculated by making use of the periodic table of elements: C: 12 + 4H: 4 = 16 g. With this information one can easily convert the volume of Methane into mass:

Mass [g] = volume [l] * molar mass [g] / 22,4 l

Filling in the above mentioned numbers one receives the following result:

Mass [g] = 10.945.607.000* 16 / 22,4 = 7.818.290.714 g = 7.818.290,714 kg

Soyaprotein was using more than 7.818 tons of CH_4, methane for the production of steam in 2008. The same calculation could be done for the export side, the off-gas if one knows the volume of CO_2 emitted. Since these data were not available, the numbers have to be calculated:

Assuming that the mass of elementary carbon is the same in the Methane as in the off-gas, one can use this number in order to calculate the number of moles contained. As already stated above, the mass of one mole of Carbon equals 12 grams. With this information one can calculate the number of moles contained in 5.863.718.036 grams of carbon (this mass is derived below). Number of moles = 5.863.718.036/12 = 488.643.170 moles of elementary Carbon. With that figure one can calculate the mass of CO_2 since the number of moles of Carbon Dioxide must be the same as for Carbon: one mole of CO_2 has the mass of C: 12 g + 2*0: 32 g = 44 grams. Consequently 488.643.170 moles of CO_2 have the mass of 21.500.299.465 grams, which equals 21.500 tons of CO_2 (see figure 16).

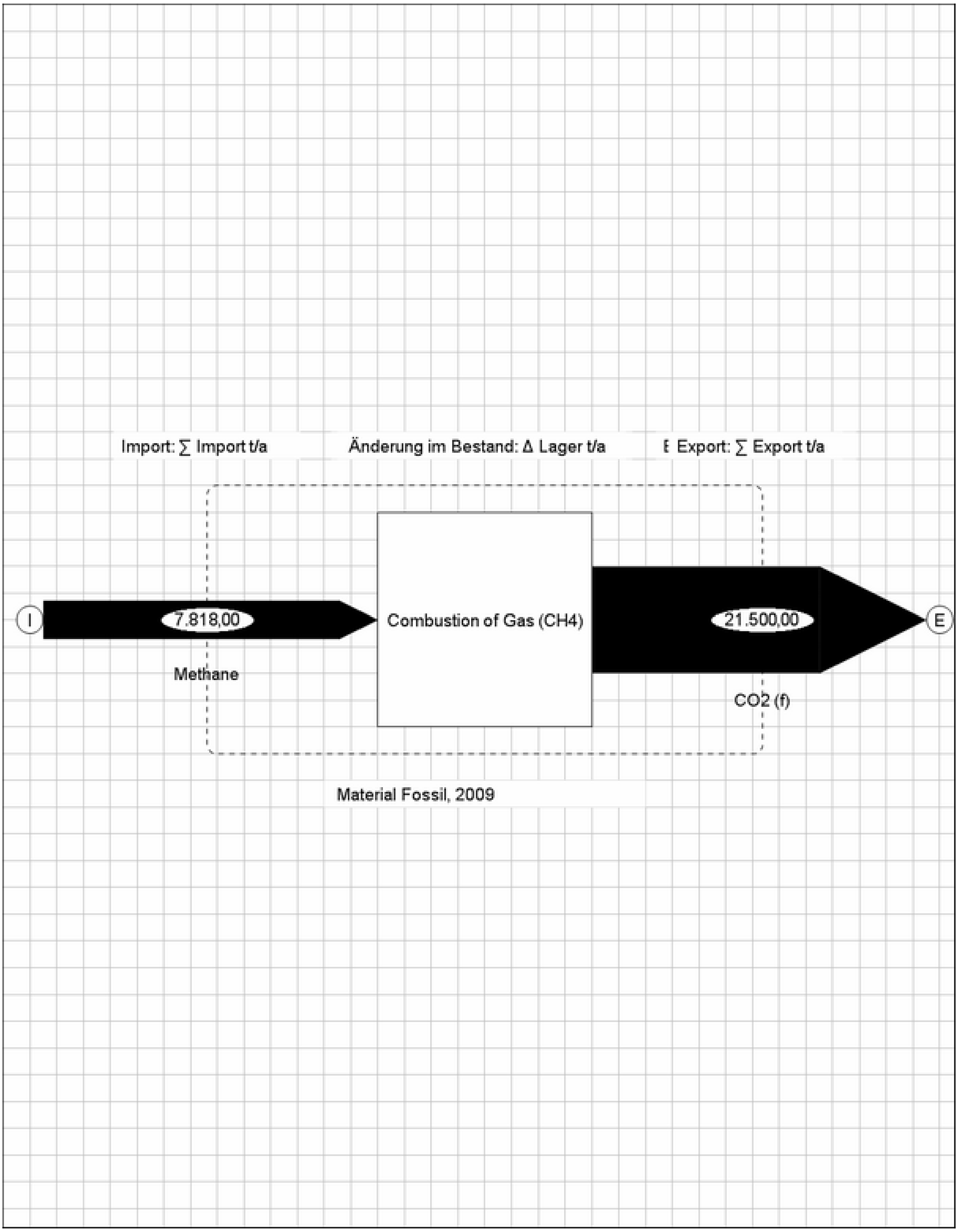

Figure 16 Average annual material flow for Soyaprotein before investment without water (source: author)

For the Carbon flow one needs to determine the share of elementary carbon contained in the molecule CH4. By dividing the molar mass of Carbon by the one of Methane, in numbers 12/16, one receives as result 0,75 – which means that 75 % of the mass of CH4 is contributed by carbon. In that way the carbon flow for the year 2008 can be calculated:
7.818.290.714 * 0,75 = 5.863.718.036 g = 5.863.718,036 kg = 5.864 tons (see figure 17).

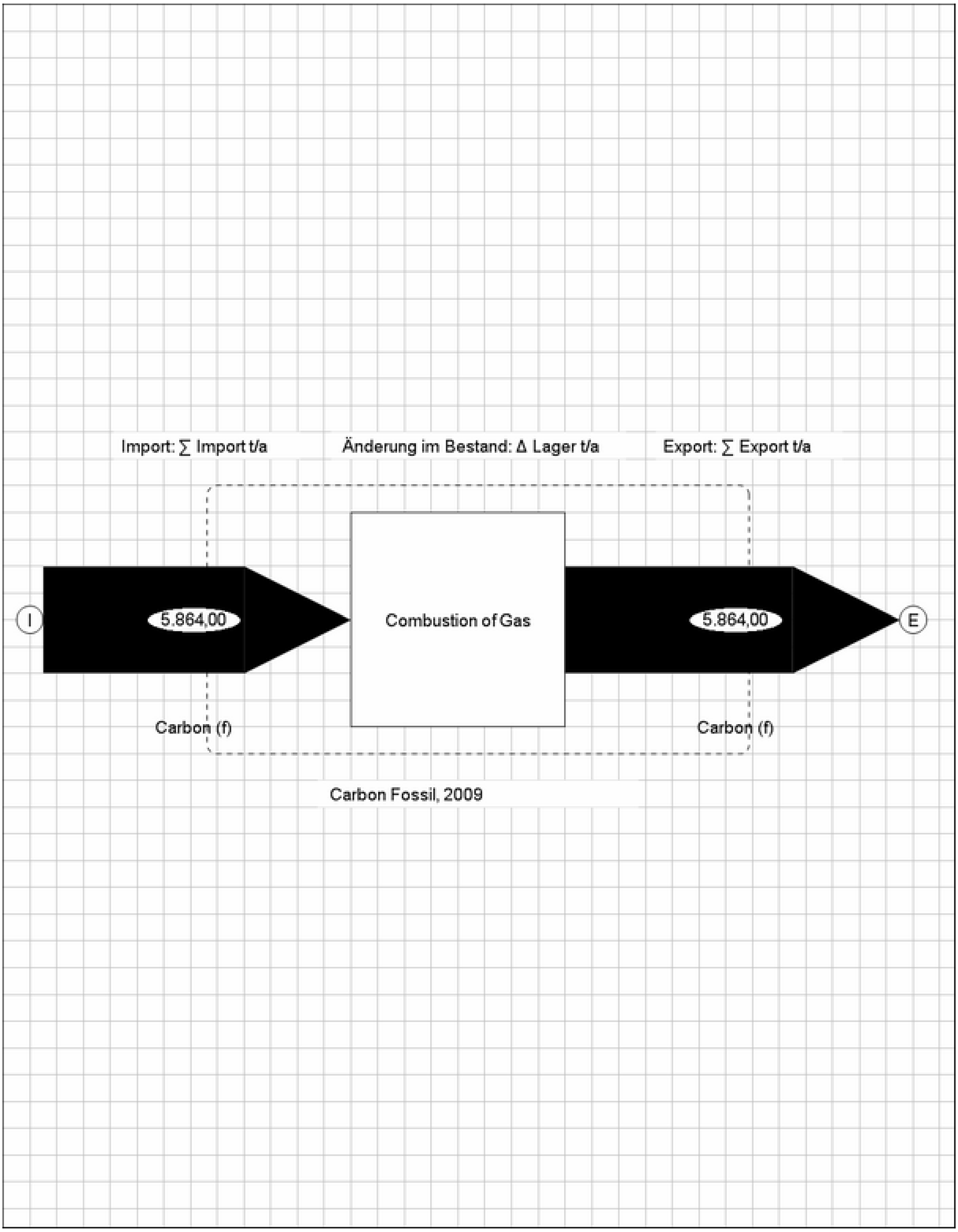

Figure 17 Average annual carbon flow for Soyaprotein before investment (source: author)

5.5.2 Situation now

Since the installation of the new boiler for the combustion of Renewable Energies, residuals of soy and sun flower, the biggest part of heat needed for the production of steam, is provided by these sources. To support the production of heat and for case of emergency, natural gas is still combusted in small quantities. Like in the example above the Material Flow Analysis again takes place at the three levels of energy, material and carbon. For the derivation of the figures for the current situation, the numbers of the first quarter of 2009, January until March, were multiplied by four. One receives 437.228 m3 of gas which equals to 437.228.000 litres. According to the above developed formula this number equals to 312.305.714 grams, 312.305,714 kilograms or 312,3 tons of Methane per year. This mass of methane contains 234.229.286 grams of elementary carbon (75%). With the above described consideration (chapter: Situation before), one can again calculate the mass of CO2 emitted by the combustion of Methane: 234.229.286/12 = 19519107,17 moles; that number of moles of CO2 have the mass of 858.840.715,3 grams. Currently the company is emitting 858,84 tons of fossil CO2 caused by the combustion of Methane per year. By using the conversion factor of 0,0342 provided by Sojaprotein one can calculate the annual energy consumption by gas: 437.228 * 0,0342 = 14953,1976 GJ. Due to a conversion efficiency of 85 %, as mentioned above, 12.710 GJ can be converted into steam, 2.243 GJ (15 %) of energy are annually lost by the conversion process.

With regard to Renewables Sojaprotein distinguishes between biomass and soy shells. The calculated annual consumption (based on the data of three months) of biomass is 14.017.396 kg. Biomass in this context is to the largest extent soy straw. The calculated annual consumption of soy shells is 2.231.000 kg.

Table 10 shows the above described numbers including carbon and energy content of biomass. The latter figures were derived from the carbon content of these resources and their heating values: 15.000 kJ/kg for biomass and 18.000 kJ/kg for soy shells.

Table 10 Energy, mass and carbon for different fuels (source: author)

	Energy [GJ]	Mass [kg]	Carbon [kg]	Carbon [%]
Gas	**14.953,20**	**312.305,71**	**234.229,29**	75
Biomass	210.261,00	14.017.396,00	4.906.088,60	35
Soy shells	40.158,00	2.231.000,00	580.060,00	26
Total Biomass	**250.419,00**	**16.248.396,00**	**5.486.148,60**	-

Per year, the total mass of biomass of 16.248 tons is producing 250.419 GJ of energy. According to information provided by Soyaprotein, the fuel-to-steam efficiency of the biomass boiler is also 85 % - the same as the one of the gas boiler. From that information the energy used for steam production and the energy lost in the conversion process can be calculated. They account for 212.856 GJ and 37.563 GJ respectively.
Assuming that biomass contains on the average 30,5 % of elementary carbon, emissions containing 5.486 tons of elementary carbon are annually produced. Making use of the above made considerations, the total mass of annual CO_2 emissions can be calculated if one assumes that there is complete combustion. That means all carbon is converted to Carbon Dioxide and there is no more elementary Carbon contained in the ash:
5.486.148.600 grams of carbon consist of 457.179.050 moles. The same number of moles of CO_2 has the mass of 20.115.878.200 grams. Consequently, the biomass serving as fuel in the new boiler produces 20.115,88 tons of climate neutral Carbon Dioxide; the CO_2 is taken up by photosynthesis by the cultivation of soy and sunflowers in the next vegetation period.

Figures 18 – 20 show the above described and calculated numbers graphically by the use of STAN software. The flows of Energy, Material and Carbon are treated separately.

One aspect that will not be further considered in the Master Thesis should be shortly mentioned:
For plant growth, three elements are of essential importance: Nitrogen (N), Phosphorus (P) and Potassium (K) – they are fertilisers for the plants. Before the soy straw was sold to Sojaprotein, it was burned directly on the fields. Nitrogen was emitted into the atmosphere, whereas Phosphorus and Potassium were still available as fertilisers for the plants in the next vegetation period. By taking away all straw from the fields and selling it to Sojaprotein, where it is combusted now, these essential fertilisers are no longer available for the plants and have to be substituted.

With regard to carbon, there is no difference between the “old” and the “new” practice – the carbon is emitted into the atmosphere in the form of Carbon Dioxide. Would the straw not have been burned on the fields but instead have remained there, the Carbon content of the soil would have had increased. In that case the Carbon Content of the soil would be needed to be taken into consideration. However there are few scientific data available concerning soil as a sink for carbon.

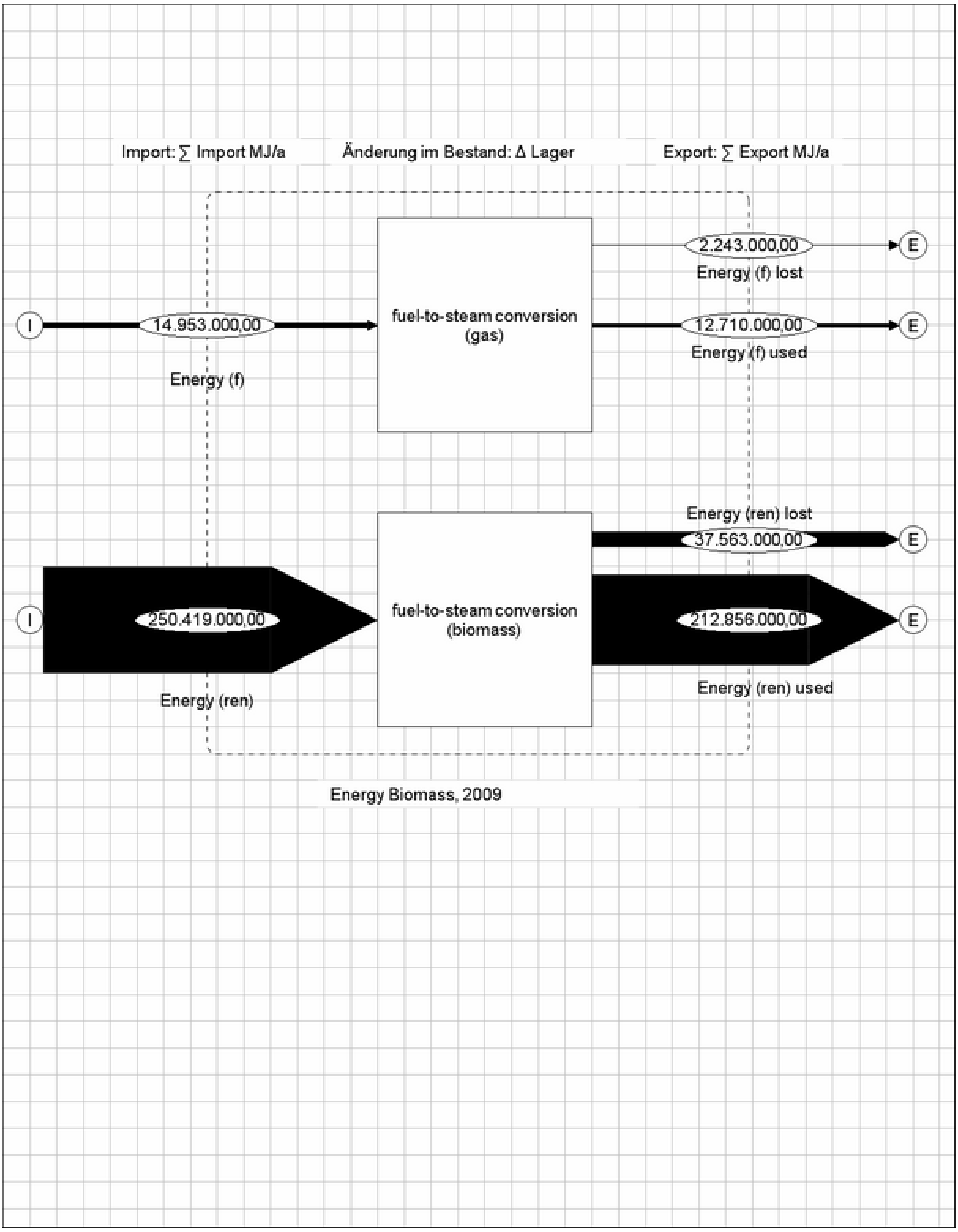

Figure 18 Energy flow after investment (source: author)

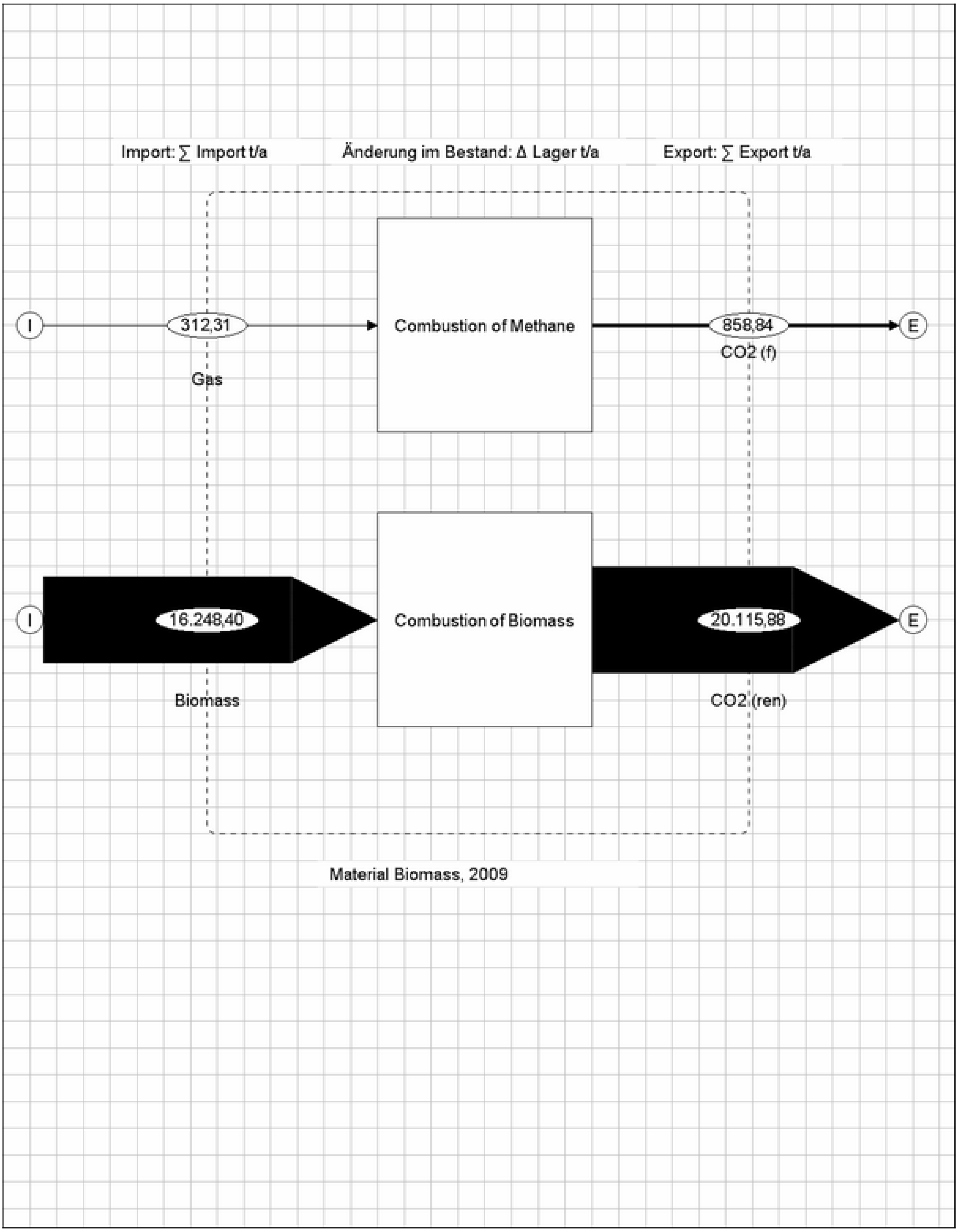

Figure 19 Material Flow after investment without water and ash (source: author)

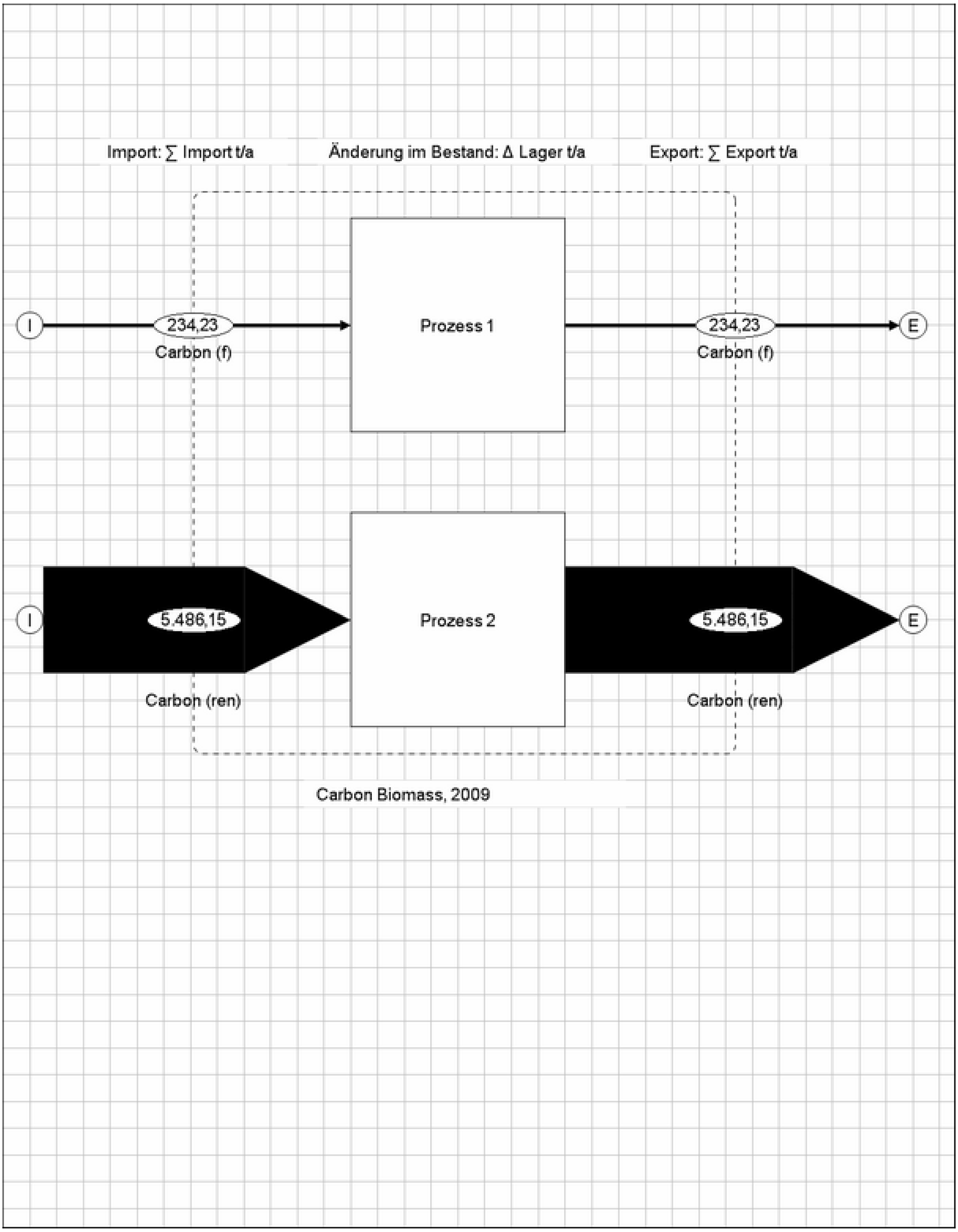

Figure 20 Carbon Flow after investment (Source: author)

By describing the situation before and after the investment with Material Flow Analysis, one fact became clear: "Fossil" CO2 emissions could be reduced significantly. Expressed by numbers: CO2 (f) emissions before the investment were accounting for 21.500 tons while after the investment they were only accounting for 859 tons per year. This constitutes a reduction of 20.641 tons/y in absolute terms or a reduction of 96 %! Put in other words, the actual emissions of fossil, climate influencing CO2 represent 4 % of the former ones. Table 11 summarises these numbers:

Table 11 Effects of investment in terms of CO2 emissions (source: author)

	Emissions Before [t/y]	Emissions Now [t/y]	Reduction [t/y]	Reduction [%]
Carbon Dioxide (fossil)	21.500	859	20.641	96

Actually CO2 emissions can be traded under the Kyoto protocol. During the 30 days from the 5th of May until 5th of June 2009 the price of one ton of CO2 was alternating around 15 Euros (see figure 21):

Figure 21 Development of the price in Euros for one ton of CO2 in the period of May and June 2009 (source: Point Carbon, 2009)

Assuming an average of about 15 Euros per ton as point of reference and by multiplying this price with the reduction of CO2 emissions per year in absolute terms one gets the result of 309.615 Euros. This amount of money can definitely decrease the time of amortisation for an investment in Environmentally Sound Technologies; it might improve the cost benefit analysis in a positive way. In the next chapter financial issues will be treated. One chapter later a cost benefit analysis will be undertaken in order to asses the possibilities and advantages of investment into technologies promoting the reduction of Carbon Dioxide Emissions.

5.6 Financial Issues

The investment of the new boiler for biomass fuel was financed by a loan given by the European Bank for Reconstruction and Development. In 2007 a € 45 million loan was given to Victoria Oil and Sojaprotein, two subsidiaries of the Victoria Group. This loan was the biggest one given until that time to a private company in Serbia. Victoria Oil is an editable oil company. It opened the first bio-diesel production facility in Serbia in July 2007; Sojaprotein, as described in more detail above, is Serbia's largest soy processing company that works with over 400 cooperatives and 40.000 farmers.

The precise description of the loan was: "Loan for the purchase of agricultural Agribusiness commodities and energy efficiency improvements." € 40 million of this loan was used for the support of Victoria Group's key editable oil crushing subsidiaries. Working capital for the finance of the purchase of agricultural commodities like sunflower seeds and soybeans was provided by this part of the loan. € 5 million were provided for investments in energy efficiency resulting in a reduction of carbon dioxide emissions. In this amount of money the investment in the installation of a new biomass boiler at Sojaprotein's production facility was included (EBRD, 2007). The improvements with regard to the environment are monitored by the EBRD: Since the loan was provided, Sojaprotein is obliged to report the improvements made, according to criteria of sustainability, on an annual basis.

The European Bank for Reconstruction and Development is the largest investor in Serbia. Until April 2009 it had committed more than € 1.4 billion in total 111 direct and regional projects (EBRD, 2009-1). EBRD's support includes major infrastructure loans for the transport sector. By improving the conditions of Serbia's road network the EBRD promotes the country's overall economic development and enables the facilitation of cross-border transport and trade. The Bank also invests in the power sector, in small and medium sized enterprises (SMEs), in private companies and new ventures. The share in the private sector is more than 50 %. Renewable energy projects and the improvement of energy efficiency are especially promoted in Serbian businesses. By doing so the bank aims to decrease carbon dioxide emissions and mitigate climate change (EBRD, 2009-2).

Figure 22 Sector breakdown of current projects financed by EBRD in Serbia (Source: EBRD, 2009-2)

Figure 22 shows the current projects financed by the European Bank for Reconstruction and Development in Serbia by sector. Infrastructure holds the biggest share, followed by the corporate sector, the financial sector and the energy sector.

5.7 Cost-benefit Analysis

This chapter will, like the previous one, deal with financial issues. In addition it will focus on a valorisation of a reduction of Greenhouse Gases in economic terms. The aim of the chapter is to show that investment into technologies which lead to a reduction of CO2 emissions can amortise in a short period already due to the given fact of lower costs for bio-fuels; they can be of even higher economic benefits if a monetary valorisation of reductions in Carbon Dioxide Emissions takes place within the framework of the UNFCCC.

According to data from the European Bank of Reconstruction and Development and to information directly given by Sojaprotein, the Investment Costs for the Biomass boiler were 4,000,000 Euros, the ones for the cleaning of the off-gas, which will be realised in the year 2009, will be 400.000 Euros. A biomass boiler without off-gas cleaning can not be considered as Environmentally Sound Technology, since air pollution would be higher in certain parameters than the one caused by traditional technology using fossil fuels like gas. For that reason one has to take as total investment cost for the biomass boiler the sum of 4.400.000,00 Euros into account.

Sojaprotein provided the quantities and costs for gas and biomass of recent years. By using these numbers a comparison of costs will be done.

Table 12 Quantities of and costs for gas in the years 2005 and 2006 and calculated, hypothetical quantities and costs for the year 2008 (source: author)

Year	**Quantities of Gas [m3]**	**Costs [Din]**	**Costs [Euro] ER: 0,01063 (2009-06-05)**
2005	11.479.001	195.776.664	2.081.105,94
2006	10.412.213	237.324.983	2.522.764,57
Everage 2005/6	10.945.607	216.550.824	**2.301.935,26**
2008	9.224.552	-	**2.576.472,00**

As shown in table 12 the years 2005 and 2006 the average use of gas was 10.945.607 m3 per year, which resulted in annual average costs of about 2,3 Million Euros. For the year 2008 the numbers were derived from the first quarter of the year 2008 in which no Biomass was yet used. The calculation gives the result of 9.224.552 m³ of gas and costs of 2,6 Million Euros. Due to variations in quantities used and the price of natural gas, costs can vary over the years. For that reason average annual costs of 2,45 Million Euros will be assumed for the situation before the investment.

For biomass, calculated numbers for quantities and costs can be used, derived from the first quarter of the year 2009. Table 13 shows the quantities of fuels and costs per quarter of a year.

Table 13 Quantities and costs for gas, electricity and biomass for the energy supply of "Sojaprotein" for two periods of three months in 2008 and 2009 (Source: Sojaprotein, 2008)

	Quantities I - III 2008.	***Quantities I - III 2009.***	***Costs I - III 2008. (EUR)***	***Costs I - III 2009. (EUR)***
Gas: [m3]	**2.306.138**	**109.307**	**644.118**	**45.804**
Electrical energy: [kWh]	6.218.100	6.569.100	237.590	249.539
Biomass [kg]	0	3.504.349	0	158.815
Soya shells [kg]	0	557.750	0	26.389
Total Biomass [kg]	**0**	**4.062.099**	**0**	**185.204**

By multiplying these numbers by the factor four the hypothetical costs for the situation now can be calculated. As shown in table 14, the use of 437.228 m³ of natural gas would cost 183.216 Euros; the one of 16.248 tons of biomass 740.816 Euros. Consequently the costs for fuel for the production of steam in the situation now, in 2009, would account for 924.023 Euros.

Table 14 Calculated Quantities and Costs for Gas and Biomass in 2009 (source: author)

	Quantities 2009	Costs 2009
Gas [m3]	437.228	183.216
Biomass [kg]	16.248.396	740.816
Sum	-	**924.032**

More information would be required in order to go more into detail. Figures concerning the improvement in energy efficiency and the precise costs for fossil fuels are not included in these considerations. Nevertheless, from the figures above, a comparison of the situation before and after the investment with regard to costs can be undertaken, as it is done in table 15. Comparing the costs before the investment of 2,45 Million Euros with the annual cost now of 0,92 Million Euros leads to a reduction in absolute terms of 1.53 Million Euros, which constitutes a reduction of costs for fuels, since the investment, of 62 %. Almost two thirds of costs for fuels can be saved per year by the investment into Environmentally Sound Technologies!

Table 15 Costs before and after the investment into the Biomass Boiler (source: author)

Costs before [€]	2.450.000
Costs now [€]	924.032
Reduction [€]	1.525.968
Reduction [%]	62,28

The period of amortisation for the investment of 4.400.000 Euros is 2,88 years, if the costs for fuel are reduced by 1.525.968 Euros per year.

Taking into account the provisions of the UNFCCC concerning Emissions Trading under the Kyoto Protocol, the economic considerations can be extended by the reduction of CO2 and their economic value. Table 16 shows the effects of the investment in terms of fossil CO2 emission. Emissions of CO2 of fossil origin and consequently relevant for climate change could be reduced from 21.500 tons per year to 859 tons per year, which represents a reduction of 20.641 tons per year (or in relative terms of 96 %). Assuming a price for CO2 of 15 Euros per ton this amount of Carbon Dioxide emissions reduced, would account for a monetary value of 309.615 Euros.

Table 16 Effects of investment in terms of fossil CO2 emissions and potential revenues for CO2 Emission Certificates (source: author)

	Emissions Before [t/y]	Emissions Now [t/y]	Reduction [t/y]	Reduction [%]	Price per ton of CO2 [Euros]	Potential Revenues for CO2 Certificates 15€/t [Euros]
Carbon Dioxide (fossil)	21.500	859	20.641	96	15	309.615

Taking this value into account by considering it in the comparison undertaken above, the economic benefit of the investment would still increase. Table 17 shows the same calculation as above including the economic value of a reduction in CO2 emissions.

Table 17 Annual costs before and after the investment into the Biomass Boiler including economic value of CO2 reduction (source: author)

Costs of fuel before [€]	2.450.000
Costs of fuel now [€]	924.032
Economic value of CO2 reduction [€]	309.615
Costs now including economic value of CO2 reduction [€]	614.417
Reduction of costs including economic value of CO2 reduction [€]	1.835.583
Reduction of costs including economic value of CO2 reduction [%]	74,92

While the costs for fuel before the investment accounted for 2,45 Million Euros, the annual costs now would account for 614.000 Euros if the economic value of a reduction of Carbon Dioxide in taken into consideration. Consequently an annual reduction in costs for fuel of almost 75 % could be achieved. The investment into the new boiler house would reduce costs for fuel to one fourth if the CO2 emission reduction achieved could be sold for 15 Euros per ton.

The period of amortisation for the investment of 4.400.000 Euros is 2,40 years if the costs for fuel are reduced by 1.835.583 Euros per year.

To sum up the considerations undertaken above: Whether the economic value of a reduction of CO2 emissions is taken into account or not, the time for amortisation of the investment is less than three years!

6 Investment Opportunities and Technology Transfer under the UNFCCC

For the investment described in the case study a financing mechanism via the European Bank for Reconstruction and Development has been found. However there are other financing mechanisms within the Kyoto Protocol which are worth being examined more closely since they are an attractive option for transition economies in general.

6.1 Introduction

The Kyoto Protocol under the United Framework Convention on Climate Change came into force in 2005. It determines the legal binding targets of greenhouse gas emissions for economically developed countries, known and Annex I countries of the UNFCCC. These countries are listed in Annex B of the Kyoto Protocol. The target of the Protocol is a 5 % reduction of Green House Gas emissions with regard to 1990 emissions levels. These reductions should be fulfilled within the period 2008 until 2012, whereas each of the economically developed countries has its own legally binding emission reduction target to be achieved.
Countries must meet their targets primarily through national measures under the treaty. The Protocol offers additional means of meeting one country's target. These means are the three so called market based mechanisms:

- Emissions trading – "the carbon market"
- Clean Development Mechanism (CDM)
- Joint Implementation (JI)

Each of these mechanisms is aiming to stimulate green investment. It helps parties to the treaty, especially countries listed in Annex B of the Protocol, to meet their emission targets in the most cost effective way.
The mechanisms under the Kyoto Protocol are all provided in Articles 6 and 17.

6.2 Market Based Mechanisms

Each of the three market based mechanisms will shortly be described in the following section. In a further step "Technology Transfer" will be defined and finally CDM will be examined more closely with regard to Serbia.

6.2.1 Emissions Trading

Emissions Trading is provided for in Article 17 of the Kyoto Protocol:

"The Conference of the Parties shall define the relevant principles, modalities, rules and guidelines, in particular for verification, reporting and accountability for emissions trading. The Parties included in Annex B may participate in emissions trading for the purposes of fulfilling their commitments under Article 3. Any such trading shall be supplemental to domestic actions for the purpose of meeting quantified emission limitation and reduction commitments under that Article." (United Nations, 1998)

The Article provides for principles, modalities, rules and guidelines for emissions trading. All Parties, industrialised nations, developing countries and transition economies are included in the trading scheme. Emission certificates can be sold by countries which are emitting less than they are actually allowed to under the Kyoto Protocol. Countries which are already emitting according to their assigned quantities are not allowed to emit more; they can however buy extra certificates from countries which have a surplus in emission certificates. The price for the certificates is determined by market mechanisms: supply and demand. Emission Certificates, also called Assigned Amount Units (AAU), are traded at the "carbon market".

6.2.2 The Cleaner Development Mechanism

The Kyoto Protocol provides for a mechanism which allows industrialised nations to invest in environmentally sound technologies in developing countries or countries with an economy in transition. The reduction in GHG emissions achieved by such an investment will then be counted for the investing industrialised nation. Many countries of the Western Balkan, like Serbia, are considered to be within the category of less developed, emerging economies where the mechanism is applicable.

The CDM mechanism has created new potential investment opportunities all over the world. Many types of projects capable to achieve additional reductions in GHG-emissions can become new investment markets for economically developed countries.

Since the beginning of the year 2006, the year in which the mechanism went into operation, more than 1.000 projects have been registered. Further projects are anticipated to produce Certified Emission Reduction Credits (CER) amounting to more than 2,7 billion tonnes of CO2 equivalents during the first commitment period of the Kyoto Protocol from 2008 until 2012 (UNFCCC, 2009). CER credits are each equivalent to one tonne of CO2. The credits can be traded and sold. Industrialised nations can use them, as described above, to meet a part of their emission reduction targets under the Kyoto Protocol.

6.2.3 Joint Implementation

Joint Implementation (JI) is provided for in Article 6 of the Kyoto Protocol:

"*1. For the purpose of meeting its commitments under Article 3, any Party included in Annex I may transfer to, or acquire from, any other such Party emission reduction units resulting from projects aimed at reducing anthropogenic emissions by sources or enhancing anthropogenic removals by sinks of greenhouse gases in any sector of the economy, provided that:*

(a) Any such project has the approval of the Parties involved;

(b) Any such project provides a reduction in emissions by sources, or an enhancement of removals by sinks, that is additional to any that would otherwise occur;

(c) It does not acquire any emission reduction units if it is not in compliance with its obligations under Articles 5 and 7; and
(d) The acquisition of emission reduction units shall be supplemental to domestic actions for the purposes of meeting commitments under Article 3.

2. The Conference of the Parties serving as the meeting of the Parties to this Protocol may, at its first session or as soon as practicable thereafter, further elaborate guidelines for the implementation of this Article, including for verification and reporting.

3. A Party included in Annex I may authorize legal entities to participate, under its responsibility, in actions leading to the generation, transfer or acquisition under this Article of emission reduction units.

4. If a question of implementation by a Party included in Annex I of the requirements referred to in this Article is identified in accordance with the relevant provisions of Article 8, transfers and acquisitions of emission reduction units may continue to be made after the question has been identified, provided that any such units may not be used by a Party to meet its commitments under Article 3 until any issue of compliance is resolved." (see: United Nations, 1998)

The Joint Implementation Mechanism of the Kyoto Protocol allows a country with an emission reduction or limitation commitment (i.e. Annex B Party of the Kyoto Protocol) to earn Emission Reduction Units (ERUs) from an emission-reduction or emission removal project in another Annex B country, which can be counted towards meeting its Kyoto target. (Within the CDM mechanism this reduction has to take place in a non Annex B country.) The two Annex B countries involved in the reduction measures can agree on a specific share in the ERUs earned for each of them.

Joint Implementation is a cost-efficient means of fulfilling a part of a country's reduction commitments under the Kyoto Protocol. The host Party benefits from foreign investment and technology transfer, while the investing party can minimise the amount of money spent per Emission Reduction Unit (UNFCCC, 2009)

6.3 Technology Transfer under the Kyoto Protocol

The transfer of technology is one important aspect which can take place in the framework of the Kyoto Protocol. Especially as a consequence of market based mechanisms technology transfer is very likely to be triggered and promoted. First of all in this chapter the term Technology Transfer will be defined in a general way. In a second step the mechanisms and institutions within the UNFCCC which are aiming to encourage technology transfer in the context of reduction of Greenhouse Gas Emissions will be examined more closely.
As a general definition of Technology Transfer one from the Journal of Technology Transfer and one from Wikipedia, The Free Encyclopaedia has been chosen:

"Technology transfer has been defined as the transfer of technical knowledge, the process of communicating research results to potential users, and the movement of technical ideas and know-how from a conceiving organisation to a user organisation at any stage of development." (See: Camp and Sexton, 1992)

"Technology transfer is the process of sharing of skills, knowledge, technologies, methods of manufacturing, samples of manufacturing and facilities among governments and other institutions to ensure that scientific and technological developments are accessible to a wider range of users who can then further develop and exploit the technology into new products, processes, applications, materials of services. It is closely related to and may be considered as a subset of knowledge transfer. Related terms, used almost synonymously, include technology valorisation and technology commercialisation. While conceptually the practise has been utilised for many years the present-day volume of research has led to a focus on the process itself." (See: Wikipedia, 2009)

Both definitions define Technology Transfer not only as the transfer of technology itself, i.e. the transfer of technical devices and facilities from one place or level to another; technology transfer is also seen as a process of sharing skills, knowledge, know how and methods. It includes "any stage of development". However with regard to technology transfer under the UNFCCC the transfer of concrete facilities and technical devices is the more relevant aspect. Apart from the above mentioned market based mechanisms, the United Nations Framework Convention on Climate Change provides for a variety of institutions and groups in order to promote the transfer of Environmentally Sound Technology (EST). This has to be seen in connection of Article 4, Paragraph 5 of the convention:

"The developed country Parties and other developed Parties included in Annex II shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention. In this process, the developed country Parties shall support the development and enhancement of endogenous capacities and technologies of developing country Parties. Other Parties and organizations in a position to do so may also assist in facilitating the transfer of such technologies." (United Nations, 1992-1)

Bodies, organisations, institutions and groups which are aiming to facilitate the transfer of technologies from Annex II (according to the UNFCCC of 1992) to developing country parties within the UNFCCC include the Expert Group on Technology Transfer and The Technology Transfer Clearinghouse. Other passages of legal texts concerning technology transfer that are worth being mentioned include Article 4, Paragraph 1c of the UNFCCC and chapter 34 of Agenda 21 the declaration finalised and published at the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992:

"All Parties, taking into account their common but differentiated responsibilities and their specific national and regional development priorities, objectives and circumstances, shall […]promote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases not controlled by the Montreal Protocol in all relevant sectors, including the energy, transport, industry, agriculture, forestry and waste management sectors." (see: United Nations, 1992-1)

"There is a need for favourable access to and transfer of environmentally sound technologies, in particular to developing countries, through supportive measures that promote technology cooperation and that should enable transfer of necessary technological know-how as well as building up of economic, technical, and managerial capabilities for the efficient use and further development of transferred technology. Technology cooperation involves joint efforts by enterprises and Governments, both suppliers of technology and its recipients. Therefore, such cooperation entails an iterative process involving government, the private sector, and research and development facilities to ensure the best possible results from transfer of technology. Successful long-term partnerships in technology cooperation necessarily require continuing systematic training and capacity-building at all levels over an extended period of time." (see: United Nations, 1992-2)

The topic of technology transfer is not new – since several decades it is relevant for the United Nations and the actual mechanisms have been prepared and developed over a longer period of time.
In order to facilitate and encourage and the technology transfer by CDM projects special authorities have been established in many countries. A project must first be approved by the Designated National Authority in order to be considered for registration. These Authorities are at a global level working since 2006 – the Cleaner Development Mechanism has by this means already registered more than 1000 projects which equals a reduction of GHG emissions of 2,7 billion tons of CO_2 equivalents. In Serbia such an authority was only recently established. The next chapter will describe the DNA of Serbia in more detail; by doing so, the functioning of a DNA in general should become clearer at the same time.

6.4 Designated National Authority (DNA) for the Implementation of CDM Projects in Serbia

Serbia is not a country listed in Annex B of the Kyoto Protocol. For that reason CDM projects can be realised on the state territory of Serbia, which account for reductions of an Annex B country. In the year 2008 Serbia's Government agreed on and established the National Authority for Implementation of Projects under the Clean Development Mechanism of the Kyoto Protocol. The Authority consists of an Expert Group and the Secretariat. The head of the DNA is the minister in charge of environmental issues. Approval of CDM projects under the Kyoto Protocol at the national level is the main task of the authority. Every CDM project which should be realised on the national area of Serbia needs to be approved by the DNA. The rules and procedures of such an approval is precisely documented in the "Rules of Procedure" published by the Serbian Ministry of Environment and Spatial Planning on the 21st of November 2008 (Republic of Serbia, 2008). In order to determine the contribution of CDM projects to sustainable development of the Republic of Serbia, indicators of sustainable development need to be used. These indicators can be found in Annex 1 of the above mentioned document. The proposed project has to meet at least one of the given indicators for each of the three sustainable development criteria.

The three criteria for sustainable development for the approval of a CDM project are the following ones:

- Economic Criteria
- Social Criteria
- Criteria concerning the Environment and Natural Resources (Republic of Serbia, 2008).

The first criterion, Economy, is dealing with investment conditions, sustainable transfer of technology, economic development of the region, employment, sectoral priorities and costs and production. In order to meet the criterion of a sustainable transfer of technology two conditions must be met: Best available technology needs to be applied, and the technology used needs to be compliant to requirements of local conditions.

Social criteria are divided into stakeholder's participation, improvement of life conditions and capacity building. Improvement of life conditions in that sense means increased employment, and an increase of revenues at a local and regional level. In poor and vulnerable communities (such as the Gipsy in Serbia) should experience an improvement of life conditions. Gender equality should be increased by the CDM project as well as public health should be improved.

Finally, criteria concerning the environment and natural resources can be subdivided into energy resources, air, water, land, biodiversity and natural resources. The criteria for energy resources are concerning fuel switch, energy efficiency, energy savings and renewable energy. A reduction of energy dependence on fossil fuels and of imports of energy-generating products is aimed to be achieved. Moreover energy intensity in all areas is concerned. A reduction in GHG emissions expressed in CO2 per capita as well as a reduction of air pollutants like VOC, SO2 and NOx should in the best case be the consequence of the implementation of a CDM project (Republic of Serbia, 2008).

7 Conclusion

Climate Change as well as energy scarcity are two high-priority issues currently faced by humanity. One possible solution to these is the substitution of fossil fuels by renewable energies. The question whether Biomass in this context can play an important role, has been treated in this Master Thesis.

It could be shown that the investment in technologies promoting Biomass as a fuel can give a considerable contribution to the reduction of GHG emissions and to a higher independence from fossil fuels. The benefits are not only of ecological but also of financial dimensions. Depending on the natural conditions concerning renewable energies of one specific region, a solution can be found which is economically profitable.

In the case of Sojaprotein, a soy processing company in Northern Serbia, this fact could be shown and proved. The case study chosen is of exemplary character for other companies located in countries with transition economies. Apart from the profitability and quick amortisation due to lower prices for fuel, facilities for renewable energy supply can be even more attractive due to specific financing mechanisms provided by international institutions. The example treated in the case study was financed by a loan of the European Bank for Reconstruction and Development, which was linked to improvements in criteria of sustainability.

Under the United Nation Framework Convention on Climate Change further financing mechanisms are provided. The Kyoto Protocol, currently in force until 2012, provides for three mechanisms. Two of these, the Joint Implementation and the Cleaner Development Mechanism, are promoting Technology Transfer into developing countries and countries in economic transition.

In December 2009, at the fifteenth Conference of the Parties, the United Nations Climate Change Conference in Copenhagen, a post Kyoto treaty should be agreed on. In this agreement the current mechanisms could be further developed, extended or substituted by new, more effective ones. One can expect that under a new Copenhagen Treaty, Technology Transfer under the UNFCCC will be promoted and encouraged even further than it is currently the case within the Kyoto Protocol.

8 References

BRAUNER, G. (2009): Renewable Energy Sources: Wind Energy, Lecture at the Vienna University of Technology, March 2009

BRUNNER, P.H. and RECHBERGER H. (2004): Practical Handbook of Material Flow Analysis, Advanced Methods in Resource and Waste Management, Lewis Publishers, Boca Raton, London, New York, Washington, D.C.

CAMP, S. M., SEXTON D. L. (1992): Technology Transfer and value creation: Extending the theory beyond information exchange, in: The Journal of Technology Transfer, 17 (1992), pp. 68-76

EBRD European Bank for Reconstruction and Development (2009-2): Country fact sheet Serbia, PDF Document published by EBRD Headquarters in April 2009, London

EUROPEAN COMMUNITIES (2001): Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market, Official Journal of the European Communities, Brussels

KRAGIC, R. (2008): Renewable Energy Sources in Serbia. Presentation for the Energy Efficiency Agency of Serbia; May 2008, Austria

INTERNATIONAL ENERGY AGENCY (2007-1): Renewables for Heating and Cooling: Untapped Potential, OECD/IEA, Paris

INTERNATIONAL ENERGY AGENCY (2007-2): World Energy Outlook 2007, OECD/IEA, Paris

INTERNATIONAL ENERGY AGENCY (2008-1): Key World Energy Statistics, IEA, Paris

INTERNATIONAL ENERGY AGENCY (2008-2): Energy Technology Perspectives 2008 in support of the G8 Action Plan: Scenarios and Strategies to 2050, IEA, Paris

ILIC M., GRUBOR B., TESIC M. (2004): The State of Biomass Energy in Serbia, Thermal Science, Vol.8 (2004), No.2, pp.5-19

NOVAKOVIC, D., DJEVIC, M.: Biomass Residues in Crop Farming, Fruit Growing and Viniculture, Development and Technology, No. NP EE611-113A, pp. 1-10

REPUBLIC OF SERBIA (2008): Rules of Procedure on the working methodology, criteria and deadlines for assessment and approval of proposed CDM projects by DNA for the implementation of CDM projects under the Kyoto Protocol, Ministry of Environment and Spatial Planning, Belgrade

REPUBLIC STATISTICAL OFFICE OF SERBIA (2003): Serbia in Figures 2003, Republic Statistical Office of Serbia, Belgrade

SOJAPROTEIN (2008): Cleaner Production Assessment Report of Sojaprotein, Sojaprotein, Belgrade

STATSERB, The Statistical Office of the Republic of Serbia (2006): Energy Balance of Electricity and Heat, 2004 & 2005, Republic of Serbia-Statistical Office, Belgrade

VTT (Technical Research Centre of Finland) (2007): Bioenergy Technology Review, VTT Technical Research Institute of Finland, Edita Prima, Helsinki

UNITED NATIONS (1992-1): United Nations Framework Convention on Climate Change, United Nations Headquarters, New York

UNITED NATIONS (1992-2): Agenda 21, United Nations Conference on Environment and Development, Rio de Janeiro

UNITED NATIONS (1998): Kyoto Protocol to the United Nations Framework Convention on Climate Change, UNFCCC, Bonn

WITHGOTT J. and BRENNAN S. (2008): Environment, The Science behind the Stories, 3rd Edition, Pearson Education, San Francisco, Boston, New York

WKO (2008): Umwelttechnik in Serbien und Montenegro. AWO-Branchenreport. Außenwirtschaft Österreich, Wien

Internet Sources:

CITY OF BELGRADE INSTITUTE FOR INFORMATICS AND STATISTICS (2006): www.zis.bg.gov.yu [accessed: 2009-05-19]

EBRD European Bank of Reconstruction and Development (2007): EBRD boosts Serbian agribusiness sector, press release published on the EBRD homepage (10 September 2007): www.ebrd.com [accessed: 2009-05-25]

EBRD European Bank of Reconstruction and Development (2009-1): EBRD takes equity stake at Victoria Group, press release published on the EBRD homepage (28 April 2009): www.ebrd.com [accessed: 2009-05-25]

FEDERAL STATISTICAL OFFICE (2001): Statistical Yearbook of Yugoslavia: www.statserb.sr.gov.yu [accessed: 2009-05-20]

POINT CARBON (2009): Point Carbon EUA/OTC assessment : http://www.pointcarbon.com [accessed: 2009-06-07]

SOJAPROTEIN (2007): About us. Homepage of Sojaprotein: www.soyaprotein.com [accessed: 2009-05-17]

UNFCCC (2009): United Framework Convention on Climate Change: http://unfccc.int [accessed: 2009-05-26]

WIKIPEDIA (2009): Technology Transfer, Wikipedia, the free encyclopaedia: http://en.wikipedia.org [accessed: 2009-05-25]

WORLD BANK (2009): Key Development Data and Statistics by country: Serbia: www.worldbank.org [accessed: 2009-05-19]

9 List of Tables and Figures