INTEGRATED DYNAMIC DECISION SUPPORT FOR SUSTAINABLE ENERGETIC USE OF BIOMASS AT REGIONAL LEVEL

CASE STUDY OF BORSOD COUNTY (HUNGARY)

DISSERTATION

by

Katalin Nóra Szarka

Chair of System Analysis and Environmental Engineering

University of Leoben, Austria

Approved by

Univ.Prof.Dipl.-Ing.Dr.mont. Jürgen Wolfbauer and

Prof. Dr. Attila Bai

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EIDESSTATTLICHE ERKLÄRUNG

Ich erkläre an Eides statt, dass ich die vorliegende Dissertation selbstständig und ohne fremde Hilfe verfasst, andere als die angegebenen Quellen und Hilfsmittel nicht benutzt und die benutzten Quellen wörtlich und inhaltlich entnommenen Stellen als solche erkenntlich gemacht habe.

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Abstract

In modern life, energy influences all human activities and is a key factor in the development of the economic, environmental and social systems on a local, regional and global level. In most European countries, also in Hungary fossil fuels represent the major source of energy, leading to import dependency and significant environmental degradation. There is a need, therefore, to diversify the energy sources and increase the use of their renewable forms for a more stable and sustainable energy supply. Previous studies have pointed out that among renewable sources the highest potential of Hungary lies on biomass. Considering that biomass use implies prosperous effects contributing to sustainable regional development in manifold ways, but also have negative effects, their complex assessment must be performed to find appropriate future solutions. This work has been based on the hypothesis that a flexible tool-set with dynamic and feedback regional features could successfully contribute to the quantification of such effects and therefore supports decision making.

Through a thorough regional analysis and structured problem analysis and SWOT assessment, the objectives of sustainable development of the study region were established. Those objectives were structured in order to define their relative importance in collaboration with regional stakeholders, using weighting methods. Specific indicators at the bottom level of the objective system were derived, set and calibrated to measure modeled future social, economic and environmental regional conditions. A system dynamics model was then built and calibrated using the Vensim® software, representing relevant regional processes governing energy fluxes and related effects and feedbacks. In the system dynamics model also the sectors of demography, economy, environment, agriculture, forests and land use are presented including validated indicators. Additionally, empirical scenarios of future sustainable biomass-to-energy processes were formulated and simulated using the model. By changing selected model components according to scenarios, quantitative evaluation of regional effects can be achieved. The simulated results of indicators were implemented into the objective system at selected points in time and in this way the level of sustainability achievement could be assessed.

The approach performed in this work includes several methodologies and tools that make it unique and innovative. The developed tool-set has proven to be flexible enough, as it allows the participation of stakeholders and decision makers from various levels. Due to its flexibility this approach is transferable for other regions or fields of study dealing with sustainable energy development. The results prove that the introduced tool-set supports decision-making in the field of sustainable use of biomass for energetic purpose at regional scale, by comparing and analyzing quantitative changes of sustainability level over time.

Kurzfassung

In ganz Europa ist der Bedarf an unterschiedlichen Quellen für die Energiegewinnung in den letzten Jahren deutlich gestiegen. Vor allem die vermehrte Nutzung von erneuerbaren Energieträgern für eine stabilere und nachhaltigere Energieversorgung hat sprunghaft zugenommen. Frühere Studien haben gezeigt, dass das höchste Energiepotential für Ungarn im Bereich der Biomasse zu finden ist. Die Verwendung von Biomasse als Energieträger implementiert jedoch auch negative Effekte, sodass eine komplexe Abschätzung für zukünftige Lösungsansätze durchgeführt werden muss. Diese Arbeit stellt die Entwicklung und Anwendung eines anpassungsfähigen Werkzeugsatz mit dynamischer Rückkopplung von regionalen Kenndaten zur Quantifizierung solcher Effekte und zur unterstützenden Entscheidungsfindung dar.

Mittels einer sorgfältigen regionalen Analyse konnten Zielsetzungen zur nachhaltigen Entwicklung der untersuchten Region strukturiert ermittelt werden. Ihre relative Bedeutung wird durch Gewichtungsmethoden in Zusammenarbeit mit regionalen Interessensvertretungen definiert. Spezifische Indikatoren wurden am Grundniveau des Zielsystems abgeleitet, festgesetzt und schließlich kalibriert, um zukünftige soziale, ökonomische und umweltrelevante Bedingungen zu modellieren. Ein dynamisches Systemmodell wurde erstellt und unter der Verwendung der Software VENSIM® kalibriert. Hierzu wurden relevante regionale Prozesse, die Energieflüsse, verknüpfte Effekte und Rückkopplungen steuern, verwendet. In dem Systemmodell sind abgesicherte Daten und Indikatoren aus den Bereichen Demographie, Ökonomie, Umwelt, Landwirtschaft, Forstwirtschaft und Landnutzung eingeflossen. Zusätzlich wurden empirische Szenarien von zukünftigen von Biomasse-zu-Energie-Prozessen entworfen und im Modell simuliert. Die simulierten Ergebnisse der Indikatoren wurden in das Zielsystem übertragen und für ausgewählte Zeitpunkte der Grad der Nachhaltigkeitsleistung bewertet.

Es kann angenommen werden, dass die gegenwärtig betriebenen Trends in der Energieproduktion die Nachhaltigkeit mittelfristig deutlich verschlechtern. Szenarien, die eine Erhöhung der Verwendung von Biomasse für die Energieproduktion zeigen einen deutlichen Beitrag zur ökonomischen, sozialen und umwelttechnischen Entwicklung. Solche Alternativen verringern CO_2-Emissionen, Erhöhen die regionale Wertschöpfung, verringern Abwanderungstendenzen der ländlichen Bevölkerung und vermindern die Abhängigkeit von importierten, großteils fossilen Energieträgern. Solche Untersuchungen, wie auch der zukünftige Betrieb von Anlagen in der Zukunft können vorgeschlagen werden und können auf einem deutlich höheren Nachhaltigkeitsgrad innerhalb des gegenwärtigen Marktes und der politischen Rahmenbedingungen bewertet werden.

Der Ansatz dieser Arbeit beinhaltet mehrere Methoden und Werkzeuge, die ihn einzigartig und innovativ machen. Der entwickelte Werkzeugsatz ist flexibel genug um die Miteinbeziehung von Interessenvertretern und Entscheidungsträgern auf verschiedenen Ebenen zuzulassen. Durch diese Flexibilität lässt sich der Ansatz auch auf andere Regionen oder Studienfelder umlegen, die sich mit der Problematik der nachhaltigen Energiegewinnung beschäftigen. Die Ergebnisse machen deutlich, dass die vorgestellte Methodik die Entscheidungsfindung im Bereich der nachhaltigen Verwendung von Biomasse für die Energiegewinnung auf regionaler Ebene durch Vergleich und Analyse von quantitativen Änderungen des Nachhaltigkeitsgrads über die Zeit ausgezeichnet unterstützen kann.

Table of contents

1. Introduction

Energy flows and services underlie all human activities as they substantially influence the economic, environmental and social systems in a local, regional and/or global level [Fritsche,2003]. Access to energy contributes to the development of rural and urban areas, bringing economic opportunities that help to eradicate poverty and ensure higher quality of life since it is an important business sector player [Weidou,2004], [Streimikiene,2007a], [Yue,2001]. Nonetheless, to meet the needs for economic growth and environmental and social concerns, the appropriate use of renewable and alternative sources as well as of sound technologies, for both energy end-use and supply, should be considered [Vera,2007]. Over the last two decades, these factors have become increasingly considered in efficient energy system planning since they make a valuable contribution to meeting sustainable energy development targets [Streimikiene,2007b], [Li,2005]. At the same time, the environmental impacts related to energy resource extraction, processing, and use are manifold [NRF,2005]. The global climate change due to greenhouse-gas (GHG) emissions (especially resulting from energetic use of fossil fuels) is one important and the most known environmental aspect [IPCC,2002]. But also other environment-related aspects, such as the decline of biodiversity due to unsustainable use of energy sources, the air pollution by acidifying substances due to land use changes and ozone precursors, the regional acidification of soils, lakes and rivers have created heavy burdens for the nature and human society [UNEP,2002], [Benetto,2004], [Mandil,2004], [Kepplinger,2002].

However, nowadays most European Union (EU)-member countries still regard fossil fuels as their primary energy source [EC,2001b]. Their depletion and expensive exploitation results in a high level of unsafe energy dependency (50% is the dependency ratio in the EU25 [EC,2004a] [EC,2005a], and 70% in Hungary [EC,2006b]). In addition, the increasing deficit of these resources has led to more vulnerable energy markets and massive changes in the energy sector of those dependent countries [EC,2001f]. To alleviate these issues, the EU is aiming to explore, develop and apply more reliable and less pollutant alternative energy sources that could also have further prosperous regional impacts, for example by increasing local value added for manufactured goods, or by fostering the local employment [EC,1997a], [EC,2001a], [EC,2006a], [EC,2006d]. New energy sources and technologies are fostered by the EU central government and supported by European laws, Directives and financial schemes (e.g. [EC,1988], [EC,1997a], [EC,2001b], [EC,2001e], [EC,2001g], [EC,2003], [EC,2004c], [EC,2007a]) and have to comply with local actual supply, demand, potential and burdens as well as with regional history, future vision and objectives (e.g. [ME,1999b], [ME,1999a], [Fehér,2006], [Koszorú,2002], [ÖI,1999], [Nagy,2005]) in order to promote the competitiveness and sustainable development at both European and regional level.

1.1. Problems in focus

This work focuses on the regional-level energy sector in Hungary. The country has compliance to international agreements (e.g. Kyoto protocol [UN,1998], [EC,2007e], [EC,2007d]) and being a member state of the EU since 2004, the activities with reference to energy production and consumption must fulfill the related EU laws, regulations and Directives. Besides, the national legal frameworks, as well as the introduced environmental concerns reveal the necessity of promoting energy efficiency, energy savings and the use of new and renewable energy sources [Bohoczky,2005], [Bai,2003], [Gács,2006], [Unk,2005]. Hungarian legislative and administrative framework on renewable energies is still in progress with several shortcomings that detain the successful process towards achieving the anticipated share of use of renewable sources. Among renewables in Hungary, a huge potential of the future energy structure lies on biomass sources, the use of which implies prosperous effects, but also negative and retardant impacts [Marosvölgyi,2005b]. Making further decisions within this framework, to find reliable biomass solutions contributing to an overall sustainable regional development, would require scientific support in several fields, which face among others the lack of appropriate know-how, data and methods available and applied. Most relevant facts detaining such complex analysis are summarized below.

1. In general, energy production and consumption have manifold effects and impacts in a region, which were analyzed in numerous studies and scales, including Life Cycle Assessments (LCA) [Benetto,2004], [Tan,2002], [Schleisner,2000], [Kim,Dale,2004], [Carpentieri,2005], [EC,2005c], [Mann,2005], [Spitzley,2005], [Hashimoto,2004], energy, emergy and exergy analysis [Hovelius,1999], [Nilsson,1997], [Brown,2002], [Odum,1996], [Kim,2004], ecological, economic and techno-economic models [Orthofer,2000], [Frühwald,2000], [Graham,2004], [Grubb,2000], [Murphy,2004], [Uddin,2004], among others. But most of those are static calculations of certain fields of study, and are not including dynamic changes over the time and feedback loops of real systems. Therefore independent results for selected points in time are available but not complex effects of future time series achieved by a holistic approach. The few dynamic models in the energy field are either in a large geographical scale, or include relative variables instead of real values [Battjes,1999], [Dyner,2005] [Flynn,2005], [Kakucs,2006;Tesch,2003], [IIASA,2001]. The behavioral characters of many of these models are limited and the majority of them generates conditional pictures of the sector's evolution, but fails to provide reliable predictions on regional components. Besides, energy sector is not an alone-standing system, but has relevant connections and interconnections with a region in which it is generated or their sources are produced, transported and converted. The tools available are not connected to other methods, such as geographical analysis or assessment methods, lacking in this manner the representation of a complex assessment.
2. There are several studies quantifying availability of biomass use on a global or national scale [IIASA,1995], [Hoogwijk,2006], [Konrad,2003], [Westergrad,2002], [Liebe,2001], [Edelmann,2001], [Bai,2005], [Klass,2004], [Lezsovits,2003], [Marosvölgyi,2000], [Nikolaou,2003], [Gill,2001], but still, only few analysis on regional level in Hungary can be found [Àrpási,2006], [Iparterv,1998]. This however is important, since areas vary strongly from each another in terms of spatial, social, economic, technological, environmental and other aspects and since the effects of biomass production and use occur at local level. Besides this region-specific, so-called 'bottom-up' approach, the recognition of a demand for increased renewable sources production and supply and its advocacy occurs as a 'top-down' role (see also in Chapter 2.3.1.1) [Hämäläinen,2002], [Gadomski,1994]. Clearly, a combination of both top-down and bottom-up cannot be found at regional planning of biomass utilization.
3. The search for new energy solutions based on biomass requires a huge amount of reliable data series from several fields and at various levels [Barótfi I.,1998a], [Kaltschmitt,2003], [Klass,2004]. However, mostly only scarce data series at regional level can be found with raw data. At the same time, data are not stored centrally, but can be found in data bases of diverse institutions and statistical offices, and their acquisition requires significant investigations. Hence, accessibility of data is often uneasy, costly or not obtainable since they must be acquired and processed from qualitative descriptions, personal conversations or other sources [Taylor,1996], [Larson,2002], [Joergensen,2004], [Könighofer,2001], [Szarka,2004].
4. The geographical distribution of energy sources availability and demand, the infrastructure and other spatial information has an important role, when analyzing biomass options [Wolfbauer,2004], [Gorddard,2001], [Geonardo,2004], [Pegg,1999]. Even so, implementation of spatial conditions to the biomass related research still does not have a high importance in Hungary.
5. Quantitative measurement of the contribution of future energy solutions to sustainable development are lacking of flexible methods and tools at regional level. To sum up the described problems, it can be stated that there is a lack of a combination of methods, concepts and approaches to support decision making in the field of renewable energy at regional level, including reliable data and information, spatial and dynamic analysis with its feedbacks. Furthermore there is a lack of being able to analyze and quantitatively evaluate complex regional effects of possible solutions and their contribution to the sustainable development.

1.2. Establishment of working hypothesis and objectives

From the above defined obstacles in the representation of energy systems, the following hypothesis can be established: for the evaluation of the quantitative, manifold contribution to sustainable regional development through utilizing biomass as renewable energy source, a dynamic and flexible tool-set could successfully contribute, if related analysis and strategies formulation are carried out at regional level, not only including the local features, objectives and potential, but the national, European and international goals and obligations as well. The tool-set should represent the region as a whole, including the energy sector in details, based on reliable data and information. It must be flexible and connected to other assessment tools for a successful quantitative evaluation of regional effects of future decisions.

From this hypothesis the main goal of this work is defined, which is to develop and implement a step-by-step method to evaluate the potential and feasibility of using biomass as renewable energy source (RES) at regional level, as well as to assess overall dynamic effects and contribution of defined realistic scenarios to sustainable regional development. Such tool is expected to support decision making of various groups of interest.

For the calibration, implementation and validation of this methodology, the county of Borsod-Abaúj-Zemplén (Borsod or BAZ) within Hungary has been selected. To achieve the main goal, the following specific objectives have been established:

1. To review the energy sector in terms of its historical and present status, legislative framework, objectives and expected future trends of relevant factors both in the EU and in Hungary and to analyze the studied area in details in order to gather and process the data and information needed.
2. To identify the main energy (biomass)-related national and regional problems and burdens of development and parties needed to be involved for such analysis, through the conduction of problem and stakeholder analyses within the case study region. Besides to identify the vision, principal goal and specific objectives of the region. This is planned through the establishment of a hierarchically-structured and components-wide weighted objective tree with bottom-level indicators, based on a carried out Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis for special characterization of the renewable/biomass sector.
3. To build and calibrate a system dynamics model, including the energy and other related sectors (population, economy, land use, economy, agriculture forestry, environment, economy, etc.) of the case study region for the representation of their systems behavior and interrelations with and within the biomass sector. To perform sensitivity analysis of insecure input data, to quantify ranges of uncertainties and possible future outcomes.
4. To determine future realistic quantitative scenarios of biomass use for energetic purpose based on regional plans identified objectives, energy sources conversion technologies and uses. To implement the scenarios into the system dynamics model, in order to define, analyze and compare future regional effects of using biomass for energetic purpose.
5. To evaluate sustainable development achievements by calculating the defined indicator values in the future simulated time and their contribution to regional sustainability.

The most innovative feature of this work is that it integrates several tools in a logical way for representing, analyzing and evaluating effects of possible biomass alternatives on a region, in a dynamic and feedback system. The built model is a contribution to system dynamics and captures the energy sector from this innovative perspective. Besides, this work also results in numerous quantitative data gathered and processed for Borsod especially in the energy/biomass sector.

2. Theoretical background

After setting the main objective of this work, which is to develop a tool-set for supporting decision making in the field of biomass to energy (BtE), before giving details about its development and application, this chapter gives an overview of background information and concepts relevant to this study, as well as a throughout description of current single tools available in decision making. The principals of the sustainable development concept are also introduced, as well as the relevance and features of the energy sector. Since the case study is a Hungarian county, its level, as well as national and European historical, current and forecasted energy patterns of various sources and sectors are reviewed, with special focus on the RES (biomass). Afterwards the description and summary of decision making theory and the characterization of its possible tools are described.

2.1. The concept of sustainable development

Future regional biomass strategies can be carried out successfully, when fulfilling the principles of sustainable development (SD). This Chapter summarizes therefore the basics of sustainability and sustainable development, projecting it to the energy sector.

Sustainability is a systemic concept, relating to the continuity of economic, social, institutional and environmental aspects of human society, as well as to the non-human environment. It is intended to be a means of configuring civilization and human activity so that society, its members and its economies are able to meet their needs and express their greatest potential in the present, while preserving biodiversity and natural ecosystems, and planning and acting for the ability to maintain these ideals in a very long term. Sustainability affects every level of organization, from the local neighborhood to a global level [Meadows,1972], [Meadows,2006], [UN,1987]. The concept of SD goes back to the 1940's, when a utopian view of technology-driven economic growth gave way to a perception that the quality of the environment was linked closely to economic development. Since then several endeavors have been made to further define and implement the SD concept in various levels. One of the important achievements was the book 'Limits to Growth' [Meadows,1972], and its 30 years update [Meadows,2006] which modeled the consequences of a rapidly growing world population and finite resource supplies, commissioned by the Club of Rome. The World3 model of this book simulates the consequence of interactions between the Earth and human systems. In 1987 the 'Report of the World Commission on Environment and Development' of the United Nations (also known as 'Brundtland Commission') defined SD as a development that "meets the needs of the present generation without compromising the ability of future generations to meet their own needs" [UN,1987]. The term SD was adopted by the Agenda-21 [United Nations,1992] program of the United Nations in 1992 as well. The 1995 World Summit on Social Development in Copenhagen further analyzed and stated that "economic development, social development and environmental protection are interdependent and mutually reinforcing components of sustainable development, which is the framework for our efforts to achieve a higher quality of life for all people" [UN,1995]. The 2002 World Summit on Sustainable Development (Johannesburg) expanded this definition by identifying the "three overarching objectives of sustainable development" to be

1. eradicating poverty,
2. protecting natural resources and
3. changing unsustainable production and consumption patterns [UN,2002].

The European Union (EU) applies the principles of the Brundtland Commission, and in 2001 prepared its own strategy, which recognizes that "in the long term, economic growth, social cohesion and environmental protection must go hand in hand" and "sustainable development offers the EU a positive long-term vision of a society that is more prosperous and more just, and which promises a cleaner, safer, healthier environment – a society which delivers a better quality of life for us, for our children, and for our grandchildren" [EC,2001a]. Its main discussed subjects are global warming and climate change, poverty, public health, aging of the population, management of natural resources, and mobility and transport[1]. Limiting climate change and its costs and negative effects on society and environment will become an increasingly important activity among these subjects, as negative effects of fossil fuel use become apparent. Therefore, the issues surrounding integration of renewable energy supplies need to be considered carefully [Visocchi-Smith,2002]. In addition, since SD cuts across many different policy and science areas, successfully contributing to its development requires an integrated approach.

Reviewing the SD's principles, milestones and main achievements, next section of this chapter highlights the consideration of how this approach should be achieved within the energy sector. Besides, the principles of the energy sector, its European and Hungarian facts and future objectives are summarized.

2.2. Introduction to the energy sector

Analysis and modeling of the energy sector is the central focus of current work, therefore, its description is given in details within this chapter. The role of the energy sector, RES, their importance and development obstructive features are therefore given. Besides, European and Hungarian energy situation in the past, present and possible future figures are summarized.

In general, energy contributes to the development of rural and urban areas through eradicating poverty, ensuring quality of life and access to clean energy services. Of further importance is the energy trade, a significant driver of globalization. The oil market already generates global price signals, while hard coal and liquefied natural gas are developing towards global markets as well [Fritsche,2003]. Major energy companies play an increasing role on the energy markets worldwide. Globalization trends can also be observed for many energy technologies, as well as energetic applications. Nowadays the CO_2 trade has become a new form of energy related trade [EC,2007c]. Energy infrastructure expenditures and energy use contribute to 10% of the Gross Domestic Product (GDP) in most industrialized (and a growing number of developing) countries. Energy furthermore is a significant part of the business sector: fossil-fuel extraction and processing is a significant source of some countries. Because of the inhomogeneous regional distribution of fossil fuel resources, the vulnerability to both turbulences on energy markets and massive changes in the energy sector is significant for many countries. The environmental impacts of energy extraction, processing, and use are manifold. Of growing importance, it can be mentioned the anthropogenic impact on the climate system from greenhouse-gas (GHG) emissions, especially resulting from the use of fossil fuels [IPCC,2002], the decline of biodiversity from unsustainable use of energy sources, the devastation of ecosystems by energy infrastructures, air pollution by acidifying substances due to land use changes and ozone precursors, regional acidification of soils, lakes and rivers, and nuclear contamination, all of which generate heavy burdens for nature and societies [UNEP,2002]. Besides, the contamination of ecosystems often accompanies the destruction or endangerment of large human communities and public risks [Fritsche,2003], from oil spills in pristine areas to nuclear contamination of population centers might occur [EC,2006b].

2.2.1. Basic terms in the energy field

There are a few basic concepts and defined terms and units of measure essential to introduce when discussing fuels, energy and their flows within a region. This chapter introduces the nomenclature used within this work based on the Energy Statistics Manual of the International Energy Agency (IEA) [IEA,2002a] [Mandil,2004] and the Statistical Office of the European Communities (Eurostat) [EC,2006b], [EC,2005a].

The term **fuel** is defined as any substance burned as a source of heat or power, whilst **energy** refers only to heat and power. When a statement covers both fuels and heat and power, the term **energy commodity** is used [Mandil,2004]. Fuels are either extracted or captured directly

[1] Over the past years several further development of the Strategy have been presented including several national sustainability strategies, as well as developed methodologies and identified indicators [EC,2004c], [EC,2005e], [EC,2005f].

from natural resources (and are termed 'primary') or are produced from primary fuels and are called 'secondary fuels'. As fuels can be primary or secondary, electricity and heat can also be called both as primary and secondary energy. Primary electricity is obtained from natural sources such as hydro, wind, solar, tide and wave power, whilst secondary electricity is produced from the heat of nuclear fission of nuclear fuels, from the geothermal heat and solar thermal heat, and by transforming primary combustible fuels such as coal, natural gas, oil or renewables and wastes. After electricity is produced, it is distributed to final consumers through national or international transmission and distribution grids [Mandil,2004]. Primary heat is obtained from natural sources such as geothermal and solar thermal power; secondary heat from the nuclear fission of nuclear fuels, and by burning primary combustible fuels. Heat is also produced by transforming electricity in electric boilers or heat pumps. Heat can be produced and used on site, or distributed through a system of pipes to structures remote from the point of production [Mandil,2004].

Primary energy commodities may also be divided into fuels of fossil and renewable origin. Fossil fuels are taken from natural resources which were formed from biomass in the geological past, such as coal, oil or natural gas. Renewable energy commodities, apart from geothermal energy, are drawn directly or indirectly from current or recent flows of the constantly available solar and gravitational energy. Within this work the distinction among energy commodities are based on this second classification, namely on the fossil and renewable forms, illustrated in Figure 1. For further analysis they are also detailed into sub-types, introduced later in Chapter 2.2.

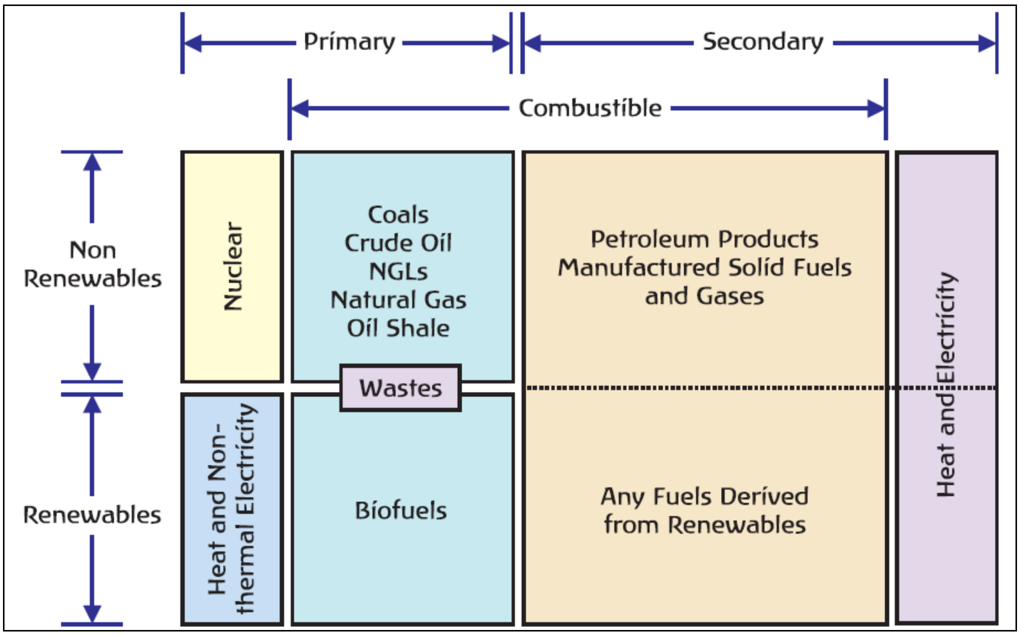


Figure 1: Classification of renewable and non-renewable sources [Mandil,2004]

2.2.2. Energy-sector related units of measurement

Fuels are measured for trading purposes and to monitor processes producing or using them. The units of measurement employed at the point of measurement of the fuel flow are those which best suite to its physical state (solid, liquid or gas) and require the simplest measuring instruments. These units are termed the **natural** or physical units of the fuel. Among natural unit the mass units can be named applied for solid fuels (e.g. kilogram and ton) and volume units for liquids and gases (e.g. liter and cubic meter) [Mandil,2004].

Once it is expressed in its natural unit, a fuel quantity may be converted for comparison or efficiency estimation. The most usual unit is the **energy unit** (e.g. kilowatt-hour), permitting the transformation of the energy content of different fuels in different physical states. This transformation requires a **conversion factor** which expresses the heat obtained from one unit of the fuel. The conversion factor defines the calorific value or heating value of the fuel, relevant ones of which are presented in Annex I.

2.2.3. Energy commodity flows

Electricity, heat and fuel can also be referred to as commodities, as described in the previous chapter. Their generation, transformation and use are going through several steps depending primarily on their origin, their applied methods, technologies and use. A short summary and classification of the commodity flows is given thereinafter.

Figure 2 illustrates the general pattern of the flow of a commodity from its first appearance to its final use [Mandil,2004]. For the determination of the commodity flow, the main stages between its arrival and disappearance (final use) have to be identified, measured or calculated, as discussed in details below. Due to the complexity, significance and manifold effects, impacts and feedback of the introduced energy sector, its successful representation requires a complex approach as well, including all interrelations of the energy sector.

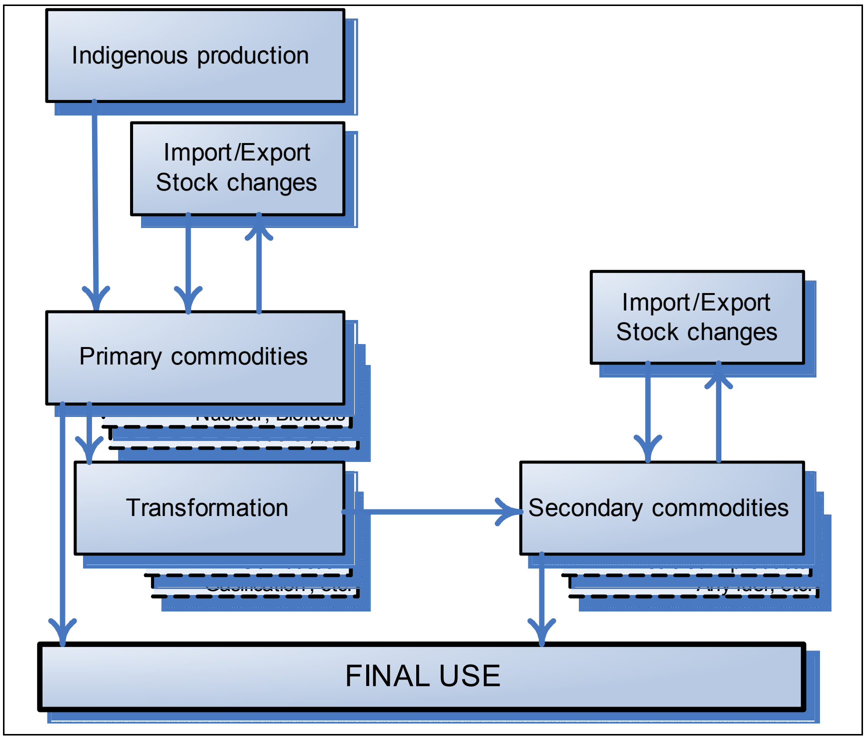


Figure 2: General pattern of commodity flow (adapted from [Mandil,2004])

2.2.4. Renewable energy sources

Energy sources can be classified into two main groups, namely fossil (coal, natural gas and oil) and renewable energy sources (RES) The latter ones (wind energy, hydro power, solar and biomass) could represent future sustainable solutions, as it was stated previously. This section gives a short description about RES with their types, formation, classification, production and consumption chain, and advantages and disadvantages of their use. Renewable energy is the energy obtained from sources that are essentially inexhaustible [Mandil,2004]. It can also be explained as if renewable energy would come from an energy resource replaced by a natural process, at a rate that is equal to or faster than the rate at which that resource is being consumed. Thus, RES according to the European Community (EC) include conventional hydroelectric power, wood, waste, geothermal, wind, photovoltaic (PV) and solar thermal energy [Mandil,2004]. RES may be used directly, or through them more convenient forms of energy can be created. If RES are extracted or captured directly from natural resources, they are called primary renewable sources, examples of which are solar ovens, geothermal heating, and water- and windmills. Indirect uses of RES - secondary sources - are produced from primary commodities such as electricity generation through wind turbines or PV cells, or production of fuels such as biogas through anaerobic digestion. When analyzing the effects and consequences resulting from processing and use of energy based on RES, as introduced at the beginning of this section, reasons of their use can be summarized as follows:

1. Significant increase in the share of renewable energy sources will play a key role in reducing carbon dioxide (CO_2) emissions [EC,1997a], [Benetto,2004], [Quirin,2004], because their conversion is being considered CO_2-neutral
2. Increasing the share of renewable energy in the energy balance enhances sustainability [Hester,2006], [EC,2001a], [EC,2001e], [EC,2005f], [EC,2004c], [EC,2005e], [EC,2006d], [MUL,2005], [WED,2000].
3. RES production and use helps to improve the security of energy supply by reducing the growing dependence on imported energy sources [EC,2004a].
4. RES are expected to be economically competitive with conventional energy sources in the medium to long term [Klass,2004], [Visocchi-Smith,2002], [EC,2003].
5. The conversion of waste to energy means a cost-effective way of reducing generated – often dangerous – waste, its pollution and environmental impact.
6. Development of renewable energy sources can actively contribute to job creation, predominantly among the small and medium sized enterprises [UN,1995], [EC,1997a], [Bai,2002]. Therefore deployment of renewables can be a key feature in regional development with the aim of achieving greater social and economic cohesion.
7. The expected growth in energy consumption in many third countries, in Asia, Latin America and Africa, which to a large extent can be satisfied using renewable energies, offers promising business opportunities for European Union industries, which in many areas are world leaders as regards renewable energy technologies [EC,1997a].
8. There is less risk to hazard to damage to ship comparing to energy generation in big plants based on fossil fuels
9. There is a general public favors development of renewables more than any other source of energy, very largely for environmental reasons [EC,1997a].
10. Development of the use of local energy sources represents new workplaces which retain local (especially rural) population; in several cases the work is required in winter period, when the unemployment is the highest.
11. Investments in new business in the region attract further (foreign) capital and contribute to innovation of the sector.
12. Due to local energy production the costs of transportation are reduced and the process can be achieved with higher efficiency, with low losses.

Besides, several other positive as well as possible hindering effects of RES might occur, for example: environmental pollution; biodiversity degradation, which, according to the form used (e.g. biofuel) is limited and not predicted with high security; acceptance of society and authorities. These effects can only be detected when analyzing them in a systematic way representing important factors of the energy system and a region connected and interconnected. The following sections give a better view about the renewable energy sources, their characteristics, quantities, potentials and obstacles.

2.2.4.1. Non-biomass based resources

In this section, first a short introduction about the non-biomass based sources is presented, pointing out their advantages and disadvantages. Afterwards the biomass source is described with all its aspects contributing the evaluation of its future application paths. Among non-biomass based sources, hydropower, as well as wind, solar and geothermal energy are shortly described. They have a common negative feature, in comparison to the biomass based sources, namely that their storage is uncertain and limited.

Hydropower

The water in rivers, oceans and streams has been long used to generate energy, as for example in wave or tidal power [Westergrad,2002]. Hydropower is the conversion of potential and kinetic energy of water - from streams, rivers, dams and other bodies of moving water - into electricity in hydroelectric plants, being these latter large or small scale facilities [IEA,2002a].

Besides the overall advantages of RES, special one can be attributed especially to a hydropower plant:

1. it regulates the water floods and the waste in the water is taken out, as it might damage the turbines,
2. there is no fuel to be transported,
3. it has a huge potential range and a long life-span [Pröbstle,2006], and
4. it has a relative little land requirement when comparing to other RES (Figure 3 represents the requirement land size by unit production of various renewable energy plants).

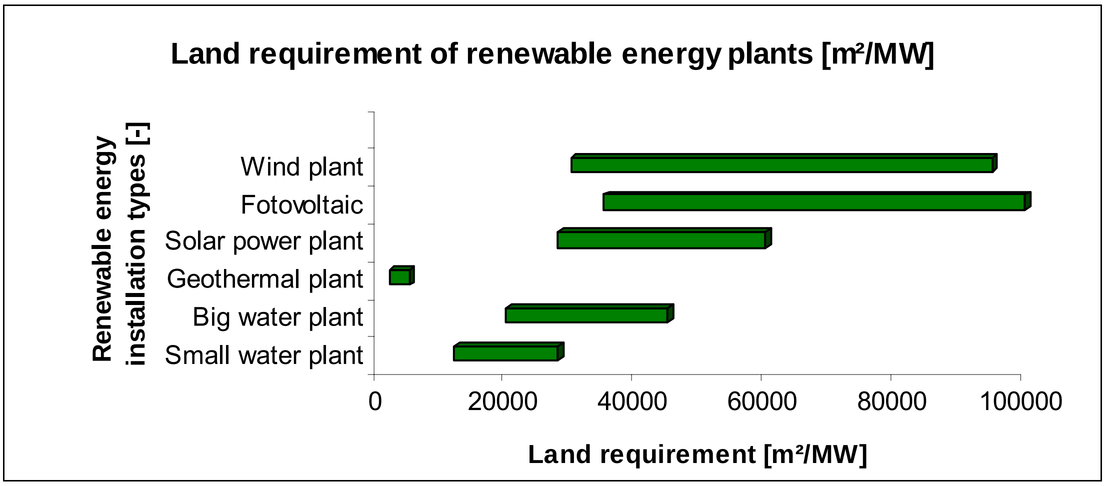


Figure 3: Comparison of land requirement for base load power generation Source: [Fazekas,2005]

Despite of these advantages, the disadvantages of especially large hydropower plants must also be revealed:

1. it implies huge investment costs, and
2. it changes/harm the ecological environment, i.e. obstruct the migration of fishes, decrease the oxygen content of the water through the stagnant water of the reservoir, damns can change natural river flows, alter water temperatures and hinder river recreation.

Wind energy

Wind power is the conversion of wind energy into more useful forms, usually electricity using wind turbines. Most modern wind power is generated in the form of electricity by converting the rotation of turbine blades into electrical current by an electrical generator. Wind power is used in large scale wind farms (mostly for national electrical grids), whilst small individual turbines - referring to 50-5000 kW capacity - are typical for providing electricity in isolated locations [Hohmeyer,2004].

In general wind power plants only have modest environmental impacts. Operational environmental problems include noise, landscape impairment, danger of accidents due to rotor-blade detachment, electromagnetic interference and negative effects on the fauna [IEA,2002a]. It does not contribute to the development of local economies. The range of its economical use is strongly limited to the local and temporal geographical and climatic conditions (wind direction, wind speed, wind power, number of days with nominal wind, elevation, etc.)

Solar energy

Solar energy is a direct radiant energy which can be used as an alternative energy source. The term 'solar power' is used to describe a number of methods of utilizing energy from the sunlight. The rate at which solar radiation reaches a unit of area in space in the region of the Earth's orbit (solar constant) is 1,366 W/m². From the energy received, roughly 19% is absorbed by the atmosphere, as clouds on average reflect a further 35% of the total energy [Patkó,1999]. Efficiency of solar energy use depends basically on the expected yearly solar radiation (kWh/m²/year), on the maximal power on the winter and summer representative days (kW/m²), the region's solar radiation coverage, and the daily solar radiation in winter and summer period (h/day). Moreover, even being a region favorable respect to the described parameters, the availability of solar is not continuous, but varies according to the weather, season and part of the day conditions [Lezsovits,2003] (characterizing also the wind energy use).

Technologies and transformations of solar energy can be classified in a number of different ways. One of the classification results in passive and active 'harness' of solar energy. Passive solar design is a broad category of solar power techniques and strategies for regulating a building's indoor air and domestic water temperatures, using climate, site features, architectural elements, and landscape materials. The goal is typically to increase the comfort, efficiency and reliability of a building, while reducing its operational costs design and dependence on other sources of energy for heating and cooling. Active solar is the use of solar energy to convert the energy in sunlight into other forms [Stumphauser,2005a]. Typical active solar systems include:

1. solar cells for generating electricity directly from the sun, also known as photovoltaic (PV),
2. active thermal solar panels, which use a transfer fluid (water or antifreeze solution) heated by the sun and fans or pumps are used to circulate the heat absorbing fluid for building heating for domestic hot water or other uses, and
3. solar hot water using solar-generated heat for heating water.

Special advantages of solar PV applications lie in that they can be integrated into the urban landscape; however its land required is the highest, up to 100,000 m^2/MW, presented in Figure 3. In addition, cost of PV has dropped significantly in the past few years and is predicted to fall even further as mass production increases.

Geothermal energy

In 1740, it was found through a mine work, that by going down into the earth crust, the temperature rises. Afterwards, in 1870 it was established the still current geothermal earth model, which says that the reason of the increasing heat is the radiogenic heat in the Earth core. According to the thickness of the Earth crust, this heat occurs in the surface and influenced by other parameters, it can be used for energetic or various other purposes.

Geothermal energy is a form of renewable energy derived from heat of the earth's crust. This heat is brought to the near-surface by thermal conduction and by intrusion into the earth's crust of molten magma. As groundwater is heated, geothermal energy is produced in the form of hot water and steam. Although the heat energy of the earth coming from the core is endless, has a diverse distribution on the Earth and only a part of it is economically exploitable [Shibaki,2003]. The most important parameters influencing the usefulness of the Earth's heat are summarized as follows:

1. the rate of increase in temperature per unit depth in the Earth is the geothermal gradient. Although the geothermal gradient varies from place to place, it averages 25 to 30 ^oC/km. This depends on the thickness of the Earth crust and influence of the temperature inside of the Earth in particular depth.
2. geological conditions, the needed pressure and a bearer to transmit the heat which usually occurs in the forms of water or vapor.

The geothermal energy can be used for various purposes, depending on the before described conditions as well as on the local conditions and demand. The purposes of using geothermal energy can be categorized in various ways. Within current study, the following classification for geothermal energy utilization is given:

- Energy production: power and heat production (for heating, cooling, drying, warm water supply, drinking water supply, etc.) in the sectors of communal, agricultural, industrial and trade.
- Other uses: balneological use, medical products, extraction of minerals and complex use (e.g. with a biomass boiler using straw or woodchips).

Besides the natural conditions, the economy is a decisive aspect for the energetic utilization of thermal waters. Commercial viability of geothermal power production is influenced by high capital costs for land, drilling, and physical plant [EK,2001], operating and maintenance costs and the market value of that power. Economy is fundamentally influenced by environmental aspects as well, namely by the necessity of reinjection which significantly increases both the investment- and operational costs of energy produced from geothermal sources as well as represent an environmental pressure. The primary impacts of geothermal plant construction and energy production are gaseous emissions (mainly CO_2 and H_2S, NO_x, SO_2), noise during exploration drilling and construction phases, potential ground subsidence and land use, however geothermal energy has a relatively low land demand. Geothermal plants besides can be sited in farmland and forests and can combined with agricultural areas as well [Fazekas,2005].

2.2.4.2. Biomass based energy resources

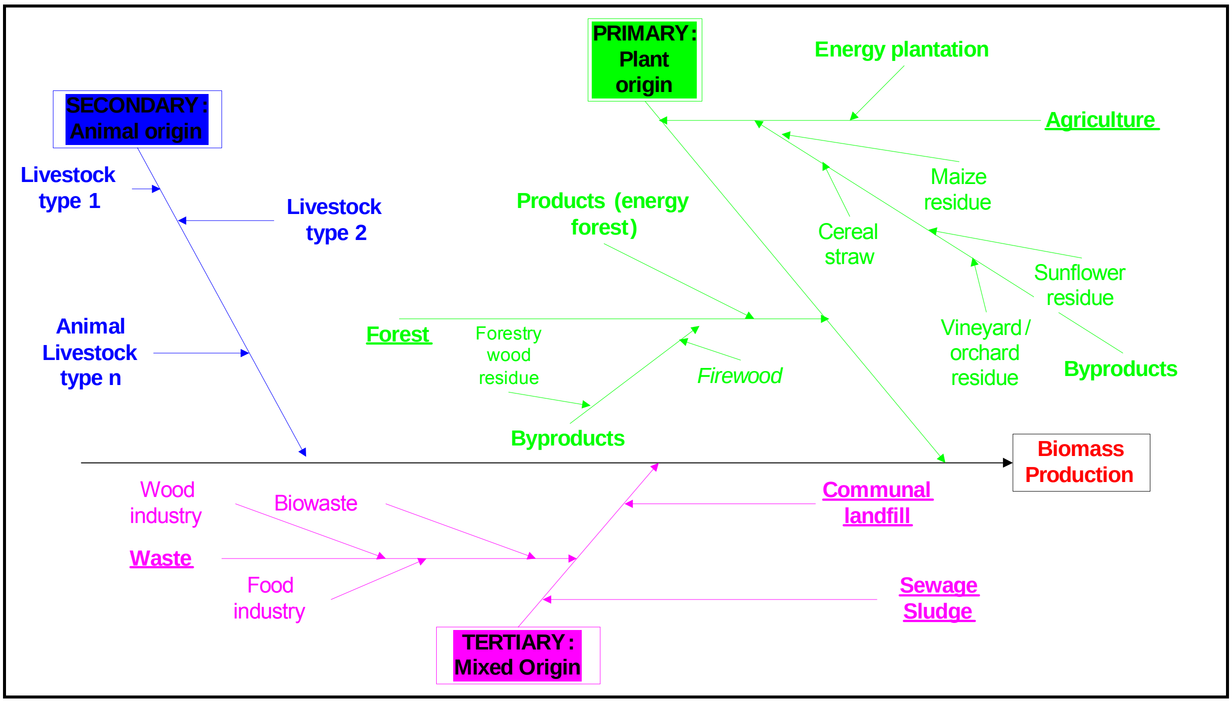
Recalling again the main objective of this work, namely supporting decisions in the field of biomass use for energetic purpose, evidently the basics of the biomass and its processes must be analyzed. Therefore first the overall principles about biomass are given in this section, along with classifications of biomass types. Afterwards, to follow the track of biomass from its formation until the use, the biomass chain is presented with detailed description of each process step. The capture of solar energy as fixed carbon in biomass via photosynthesis, during which carbon dioxide (CO_2) is converted into organic compounds, is the key initial step in the growth of biomass, as depicted generally by Equation 1:

$$CO_2 + H_2O + Light + Chlorophyll = (CH_2O) + O_2 \qquad \text{Eq. 1}$$

Carbohydrates, represented by the building block (CH_2O), are the primary organic product. For each gram mole of carbon fixed, about 470 kJ (112 kcal) is absorbed. The upper limit of the capture efficiency of the incident solar radiation in C_3 plants is estimated to 0.1-1%, in C4 plants to 1-2% and in algae to 2-2.5%.

Biomass classifications

Classification of biomass can be made based on various aspects; within the Hungarian nomenclature biomass classification is represented in Figure 4



and listed below [Bai,2003]:

1. primary (plant origin) biomass: especially agriculture origin main- and byproducts,
2. secondary (animal origin) biomass: consumers of primary biomass and byproducts, and
3. tertiary (mixed origin) biomass: biomass-origin waste, non-homogeny biomass process byproducts, recycling biomass, etc..

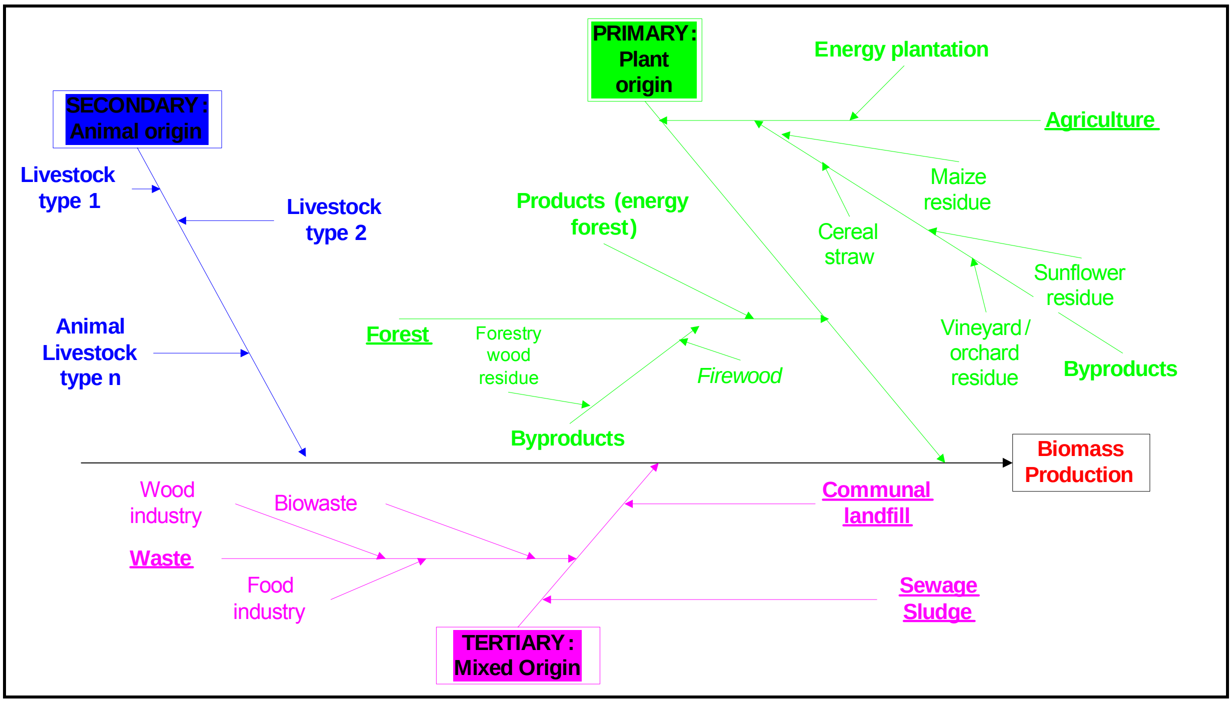


Figure 4: Fishbone diagram of biomass origins

According to the EC definition, biomass shall mean "the biodegradable fraction of products, waste and agricultural residues (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste" [EC,2001b]. The EU's classification of biomass forms [Mandil,2004] is the following (summarized also in Table 1 [Jungmeier,2004]):

1. Solid biomass covering organic, non-fossil material of biological origin, which may be used as fuel for heat production or electricity generation. It comprises charcoal (solid residue of the destructive distillation and pyrolysis of wood and other vegetal material) and wood, wood wastes and other solid wastes. Wood, besides traditional forestry, includes purpose-grown energy crops (poplar, willow, etc.), a multitude of woody materials generated by an industrial process (wood/paper industry in particular) or provided directly by forestry and agriculture (firewood, wood chips, bark, sawdust, shavings, chips, etc.) as well as wastes (such as straw, rice husks, nut shells, poultry litter, crushed grape dregs, etc.). Biodegradable municipal solid waste produced by households, industry, and the tertiary sector can also be incinerated at specific installations [Mandil,2004].
2. Liquid biofuels, mainly biodiesel and bioethanol/ETBE used as transport fuels. They can be produced based upon energy crops (lignocelluloses, oil seeds, sugar crops or starch crops), forestry residues, liquid manure or other waste, for example cooking waste oil.
3. Biogas, composed principally of methane and CO_2 produced by anaerobic digestion of biomass, comprising:
   3.1. landfill gas, formed by the digestion of landfilled wastes,
   3.2. sewage sludge gas, produced from the anaerobic fermentation of sewage sludge and
   3.3. other biogas, produced principally from the anaerobic fermentation of animal slurries and wastes in abattoirs, breweries and other agro-food industries.

Table 1: Relevant biofuel types (Source: [Jungmeier,2004])

		Biobrickett /biopellet	Bioethanol, Bio-ETBE (Ethyl Tertiery Butyl ether)	Bio-diesel	Bio-dimethyl-ether	Biomethanol Bio-MTBE (Metyl Tertiery Butyl Ether)	Syntetic biofuel	Bio-hydrogen	Biogas
Energy crop	Lignocell ulose	+	+		+	+	+	+	
	Oil seed			+					+
	Sugar crop		+						+
	Starch crop	+	+						+
Forestry residues		+	+		+	+	+	+	
Liquid Manure									+
Other Waste				+					+

Current study deals with lignocelluloses biomass originated from **agriculture and forestry** sector, therefore they are detailed afterwards. Generally, the biomass fuels resulted from these sectors have low ash content, but there is a great difference between the ash behaviors of different sources. After harvesting, the biomass has a relatively high water content (it also varies in a wide range in every crop case), which lowers increasingly during storage or treatment, a stage that has a considerable effect on the heating value and firing behavior as well. General advantages of using biomass as energy source are on the one hand the ones referring to the use of all RES, including their contribution to mitigate especially GHG emissions. Use of biomass enhances security of energy supply and its decentralization, when applying in small scale. On the other hand specific advantages of biomass use can be summarized as below:

- Biomass resources are often locally available and conversion into secondary energy carriers is feasible.
- Biomass technologies develop dynamically, and therefore the obtained achievements and know-how allow deducing the fall of investment cost, depending on the process applied. Surely selection of appropriate process is influenced by other costs and the marketability.
- Biomass based energy can affect positively degraded land by adding organic matter to the soil, when recovering these areas for energy crops.
- Most types of biomass are available in any areas without requiring special characteristics or high quality features
- Energy obtained from biomass can play an important role in an appropriate use of land (some plantations could be established in areas where other production would not be considered rentable).
- Energy plantations may create new employment opportunities in rural areas, contributing to social development [Hoogwijk,2006].

Despite the several advantages of biomass use, its barriers also have to be taken into consideration, among them the cost (fore example associated with connecting to electricity network, capital investment or transport) is the most significant. Further possible barriers of widespread use of biomass usually are the following ones:

- Unstable biomass markets lead to need for fixed-term contracts for the fuel supply.
- Uncertainty in fuel availability and price.
- There are large number of small to medium sized wood processing companies which typically do not invest in research and development, resulting in lack of sound information.
- Energy crops face competition with food and fiber crops for suitable land.
- Slow uptake and often poor image in innovative technologies, often lack of strong government subsidies [Westergrad,2002].

Biomass chain

To follow the track of biomass from its formation until its use, the biomass chain is introduced in this section. After producing and extracting biomass it is transported either to the conversion or final use location, or stored transitionally. Through storing the biomass fuels, it can be utilized in the period when energy is needed, independently from its production. The last steps before its use are the conversion and transmission. As example, a simplified woody biomass chain containing all these steps is shown in Figure 5.

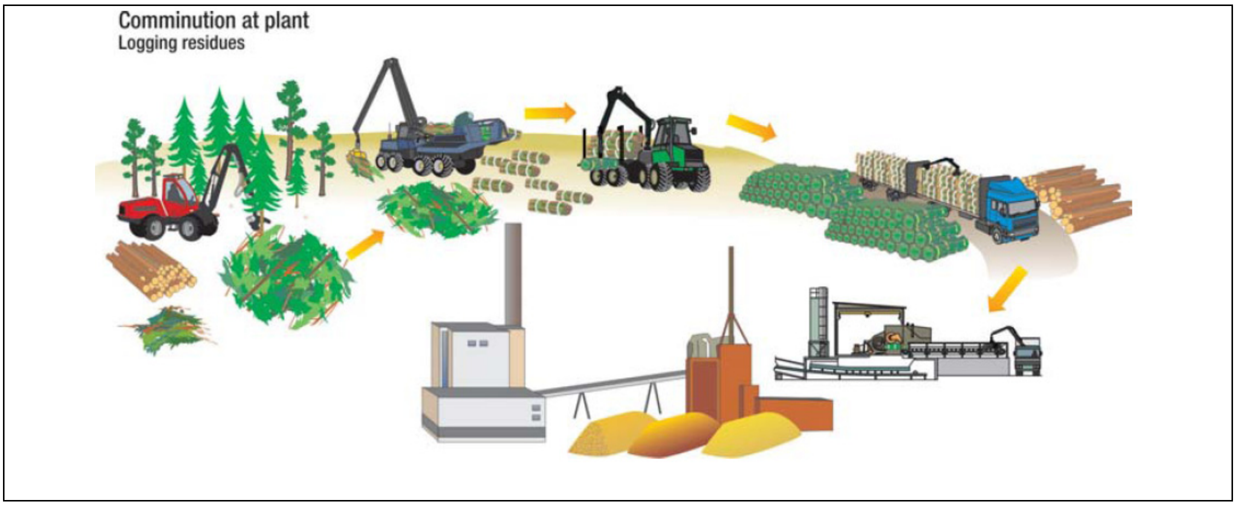


Figure 5: Example process of woody biomass production to consumption Source: [Pentti,2004]

Biomass production/generation

First step of the biomass process is its production or generation. According to the origin, different resources can be gathered, which are listed in Table 2. The representative sources of this study, agriculture and forestry, are further described in Chapter 4.6.

Table 2: Classification of the biomass fuel resources, based on [Nikolaou,2003]

SECTOR	RESOURCE	
Agriculture	agricultural residues	straw, corn-stems, lopping and grape cane
	livestock waste	dry manure (poultry litter)
		liquid manure
	energy crops	energy grass (Miscanthus, Szarvasi 1)
		oil crops (oilseed rape, sunflower)
		sugar/starch crops
	other	other herbaceous crops (silo maize)
		short rotation coppice (SRC)
Forest	traditional sylviculture	wood fuel (firewood)
		forest residues
Industry	industrial residues and by-products	organic byproducts (food industry)
		wood waste (wood processing industry)
Waste	municipal waste of biomass origin	landfilled waste
		sewage sludge
		selectively collected municipal biowaste, cut grass
		waste vegetable or other oils
		regular cleaning activities of parks and gardens (urban wood, cut grass, etc.)

Intermediate processes in the biomass chain

When biomass is produced or generated, it can be extracted and transported to the area of landing or at the end-use site, and – if needed – stored. Intermediate processes of biomasses stand special characteristics, depending on terrain, logging density, roadside space, and procurement areas with certain size or site geometry. The extraction and transport of biomass consist of various activities, including felling, bundling, forwarding of bundles to road, chipping at the landing or at the end-use site and transporting of unprocessed and processed material. There are countless possible combinations for the steps of various biomass processes, the quest and itemization of all are not the objective of this work. Whereas the sub-activities of the later selected biomass strategies will be introduced and described in Chapter 5.6.

Biomass processes and conversion technologies

When biomass is produced and transported to the conversion site, it can be converted into various forms of energy commodities (electricity, heat or fuel) through several conversion methods, which are summarized in Figure 6 based on [Kaltschmitt,2000].

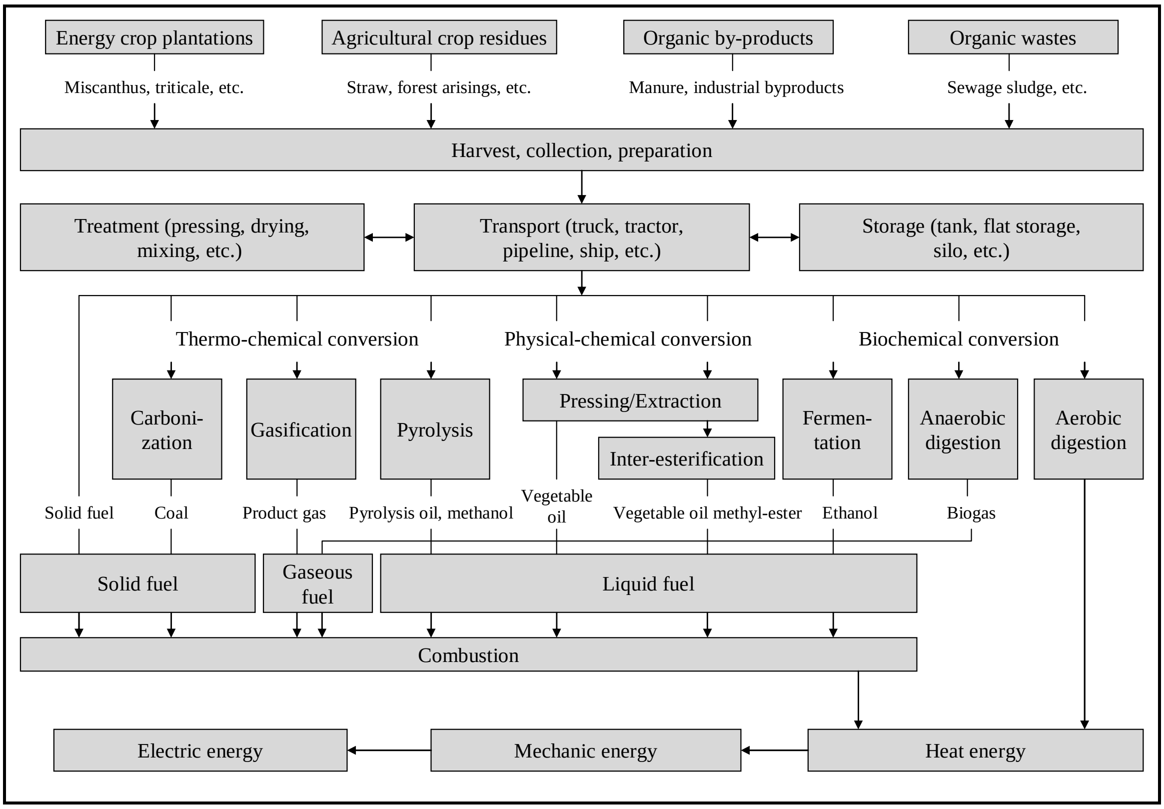


Figure 6: Overview of the biomass-to-energy process [Kaltschmitt,2000]

Most applied conversion methods are described below.

- Combustion is a process in which the fuel is burnt with oxygen to release chemical energy as heat in burners, boilers, internal combustion engines and turbines. It is the most common application of biomass to provide heat and power [Sims,2004]. A realistic scale of biomass combustion devices encompasses 10 kW to 10 MW [Barótfi,1998].
- Anaerobic digestion is the decomposition of biological matter by micro-organisms, usually under wet conditions and in the absence of oxygen, to produce a gas (biogas) comprising mostly methane and carbon dioxide with various trace elements [U.S.Department of Energy,2006]. This can be used to generate heat and electricity via engines and gas turbines, but also for transport applications and could be converted to hydrogen [Kakucs,2006]. Anaerobic digestion is applied in the treatment of (wet) wastes arising from agricultural, industrial and domestic origin (such as animal manure, organic by-products from food processing and sewage sludge) [AGORES,2006].

- Gasification is the conversion by partial oxidation at elevated temperature of a carbonaceous feedstock into gaseous fuel. The product gas can be utilized to generate heat and electricity by direct combustion in engines, turbines and boilers after suitable clean up [ICLCEPT,2003].
- Pyrolysis is a similar process to gasification, but it is carried out at a lower temperature, and with few or no air, encouraging more pyrolysis oil and charcoal to be produced [Visocchi-Smith,2002]. The end product of pyrolysis is a mixture of solids (char), liquids (oxygenated oils), and gases (methane, carbon monoxide, and carbon dioxide) with proportions determined by operating temperature, pressure, oxygen content, and other conditions [U.S.Department of Energy,2006]. Through the condensation of organic gases, high energy containing oil can be gained, and the other gases can also be used for energy purpose. Pyrolysis is still at the early pilot-plant stage of development [ICLCEPT,2003].
- Inter-esterification is the conversion of oil crops into vegetable oils for automotive fuel applications (biodiesel). The process starts with the oils' extraction from oil seeds by mechanically pressing or extraction with a solvent, like hexane: Afterwards the oil is made suitable for engines in road vehicles through esterification, through transforming large, branched molecule structures of the oils (triglycerides) into smaller straight-chained molecules (methyl esters). One widely used methyl ester is the Rapeseed Methyl Ester (RME), produced from rapeseed vegetable oil [E.van Thuijl,2003].
- Fermentation is a conversion of carbon-containing compounds by micro-organisms for production of fuels and chemicals such as alcohols (bioethanol), acids or energy-rich gases [U.S.Department of Energy,2006]. Suitable crops for bioethanol production are sugar-containing crops (such as sugar beet, sugar cane, and sweet sorghum), and crops containing starch (e.g. potatoes, barley or maize). The produced bioethanol can be used as a transportation fuel in pure form, mixed with petrol or in the form of Ethyl Tertiery Butyl Ether (ETBE), among others.
- Compression: Through drying and compressing lingo-cellulosic materials at very high pressure, briquettes (~65 mm diameter) or pellets (6-16 mm diameter) can be produced having high density and heating value. The process might include the following steps: storing and pre-treatment of the raw material, (drying) and compressing it, (cooling) that storing.

The development stages of described processes are summarized in Figure 7. Selected biomass based heat and power plants in Hungary and other European examples are summarized in Annex II.

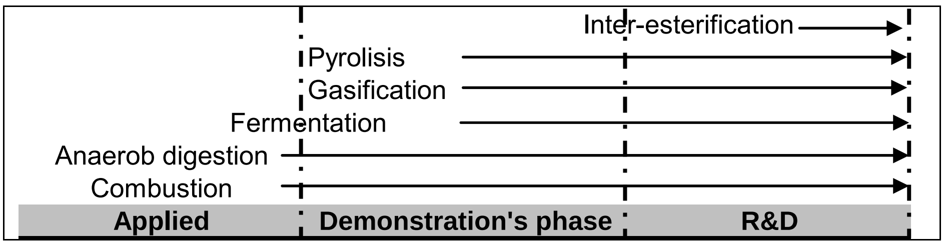


Figure 7: Development stage of biomass conversion methods (after [Barta,2003])

Biomass consumption

Following the conversion of biomass, it can be used in the form of heat, electricity or transport fuels. Any sector of a society, namely households, agriculture, industry, services, trade and transport can be considered as consumers. The detailed description of these sectors in Borsod is introduced in Chapter 4.8.

Through introducing the basics of biomass production and conversion, it can be stated that all energy systems, both renewables and fossil, have a range of positive and negative impacts on the region's environment, economy, technology, as well as on the social dimensions. To decide on the most appropriate local energy forms to be applied in the future, a general analysis of RES is not sufficient. Since its production as well as use of energy forms, the technological and infrastructural conditions, economic circumstances, social and environmental situations diverse from area to area, these aspects must be analyzed in details at regional level. Therefore, the reveal of local geographic, social, political, environmental and economic features, and quantitative renewable (biomass) potential, as well as existing energy use customs and future objectives and expectations are investigated. Besides the overall EU and national laws and regulations, political and administrative conditions are described and summarized in the next Chapter.

2.2.5. Energy perspectives in the European Union

After a general description of RES, their types also must be analyzed within European level; past and current figures about energy productions and uses are introduced in this section.

The enhanced standard of living and developing industrial production is resulting in continuously rising energy consumption in the EU, which reached 1,560 Mtoe in 1990. However, the share of renewables in the summarized gross inland energy consumption (GIC)[2] was only 4.5% (compared with 16.7% gas, 38.4% liquids, 27.7% solids and 12.7% nuclear), whilst the share of renewable electricity in gross electricity consumption only reached 13.4% in the EU15 in the year 1990 [EC,2006b]. Besides the increased consumption, the production of energy sources sank continuously in the last years which resulted that Europe is being characterized by a high level energy dependency: 45% was the level of total energy dependency of EU15 in 1990 [EC,2004a]. With the amount of 3,112 million tons of CO_2 emission, the EU15 participated to 15% of the total CO_2 emission from energy [EC,2006b].

2.2.5.1. Towards a sustainable energy policy

The described facts about the European energy situation could undermine the recovery of the European economy, social stability and environmental security. Besides, the connections between the energy sector and economic growth, environmental and human health, agricultural productivity, information and communications technologies etc. underline the role of the energy sector for a sustainable development. Therefore the EU has included the energy sector and the concerned endeavors within its sustainability strategy. According to that the key principals of sustainability in energy sector are formulated as next:

1. As economic wealth is unequally distributed between countries and regions, and access to energy services differs significantly among countries, at a minimum, a sustainable energy policy must guarantee equal opportunities to access basic and secure energy services for all society members at the present, as well as for future generations.
2. Environmental burdens must be limited to a level that ensures the life-support functions of the environment, nature and biodiversity in the long-term.

Latest EC-document, the ‘Renewed EU Sustainable Development Strategy’ [EC,2006c] define the following goals: improve resource efficiency, reduce the overall use of non-renewable natural resources and the related environmental impacts of raw materials use, abate the energy dependency, promote energy efficiency and energy savings, maintain the security of supply, thereby using renewable natural resources at a rate that does not exceed their regeneration capacity. These goals also consort with the ones formulated for economic and social development, namely achieving the increase of value added or contributing to creating further jobs [EC,2005b]. The setting of new targets shall be justified on the basis of a thorough analysis of the potential and cost-effectiveness of further measures as well as complex analysis of regional effects resulting from use of renewables. To achieve the defined targets, the EC has established and applied several laws, regulations, directives or support schemes, which are summarized in Table 3.

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[2] Gross inland consumption is the quantity of energy consumed within the borders of a country. It is calculated using the following formula: primary production + recovered products + imports + stock changes - exports - bunkers

Table 3: Energy related significant international agreements and Directives [UN,1992], [UN,1998], [EC,1997b], [EC,2001d], [EC,2001b], [EC,2003], [EC,2007d]

Type of activity	Name	Year	Main subjects
Agreement/Directive	Agenda 21	1992	Definition and establishment of the principles of sustainable development Reduction of energy consumption Encouraging greater efficiency in the use of energy and resources Encouraging the environmentally sound use of new and renewable energy sources
	Kyoto protocol	1997	Commitment of 163 countries to reduce their emissions of carbon dioxide and five other greenhouse gases. For the new EU25 it is an average of 8% between 2008 and 2012 compared to the year 1990.
	White Paper	1997	Double the share of renewable energy from 6 to 12% in Gross Inland Production by 2010. New initiative for transport, heat and electricity based on RES Define internal market measures
	Green Paper	2000	Increase the security of energy supply Value of taxation measures to steer demand towards better-controlled consumption
	2001/77/EC	2001	Promotion of electricity from RES: 21% of EU gross electricity consumption should be derived from RES by 2010
	2003/30/EC	2003	Increasing up to 5,75% the use of biofuels by 2010
	COM(2007)1 COM(2007)2 COM(2006)545	2007	20% share of renewable energies in overall EU energy consumption by 2020; reducing the emissions of greenhouse gases in the order of 20 % by 2020 compared to 1990; to achieve the objective of saving 20 % of the EU's energy consumption compared to projections for 2020; 10% share of biofuels in overall EU transport petrol and diesel consumption by 2020
Support programs	4th Framework Programme	1994-1998	Research and development in the field of innovative energy technologies and demonstration of these energy technologies
	5th Framework Programme	1998-2002	The quality and sustainability of the use of natural resources and ecosystems, threats of global change, quality of life in the cities, and the impact of the production and use of the energy which is essential to our economies and to the way of life, and also centrally important in environmental problems, notably climate change.
	6th Framework Programme	2002-2006	Strengthening the scientific and technological bases of industry and encourage its international competitiveness while promoting research activities in support of other EU policies.
	7th Framework Programme	2007-2013	Achieving growth, competitiveness, employment, education and training and regional convergence.

2.2.5.2. *Indicators of energy patterns*

The described objectives have been partially implemented and/or are in progress of implementation and further development in the EU, which resulted in some changes in its energy sector during the last years. To analyze and quantitatively compare the energy situation over time and among countries, energy-related indicators have been introduced and applied, from which selected relevant ones are displayed in Figure 8, comparing to their reference value of 1990, which is equal to 1.

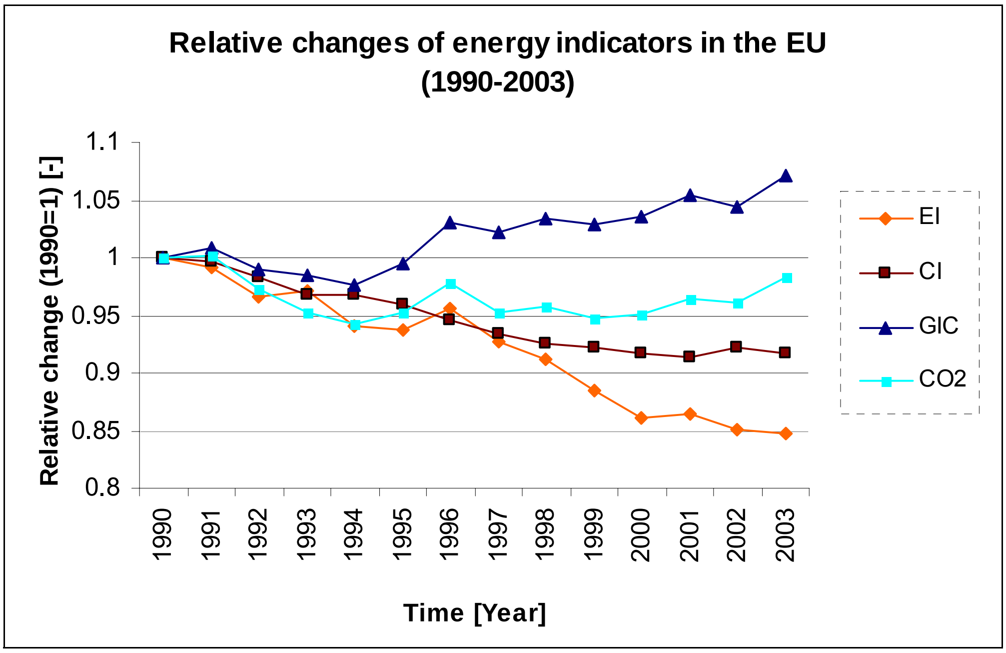

Figure 8: Relative changes of energy indicators in the EU from 1990 to 2003 [EC,2005a]

Notes: (1) GDP is at 1995 prices; (2) *EI=Energy intensity, CI=Carbon Intensity, CO_2= CO_2 emission*

The gross inland consumption (GIC) of energy is continuously increasing within Europe, whilst that related to Energy intensity (EI) is declining which can be explained with a more intensive GDP increase over the last years. From Figure 8 it can also be stated that the CO_2 emissions are increasing; both related to the population and in comparison to the GIC, for what especially the transport and energy sectors can be named responsible. The share of fossil fuels in total energy consumption declined only slightly between 1990 and 2003. Pressures on the environment were reduced by a fuel switching from coal and lignite to gas, a relatively clean energy source, mainly in power generation[3].

Taking a look to the actual values of energy production and consumption within the EU25, the following values are representative: 1,750 Mtoe is the yearly final energy consumption, compared to the 850 Mtoe production [EC,2006b]. As a result, its external dependence on energy is constantly increasing: from 45% in 1990 [EC,2004a], to almost 50% of EU25 in 2003 [EC,2006b] and expected to grow up to 70% without further activities [EC,2001c]. Greatest dependency levels have the fuels oil (76.6%) and gas (53%). The insufficiency is in some regions also threatened by insecurity - the oil is mostly imported from Russia, Norway and Saudi Arabia, Libya, Iran and other Middle East countries, whilst main gas importing countries are Russia, Norway and Algeria. These facts draw the EU's attention to the urgency of the alleviation of its dependency [EC,2005a].

2.2.5.3. Energy mix alongside the European Union

For a more complex picture about Europe's energy sector, the energy mix is described hereon. Electricity generation of the EU25 reaches 3,121 TWh in year 2003, whereby 399 TWh were generated from renewables (13%), furthermore coal-based and nuclear energy take 31%-31% and gas 19%. 73% of the renewable electricity's sources are coming from hydropower, 15% from biomass sources and 11% is wind energy (Figure 9*a)*.

[3] However, natural gas has several environmental loads (especially much higher CO_2 emission than by using renewables); moreover, 53% of its consumption in the EU is imported, which strongly puts a question mark on its sustainability.

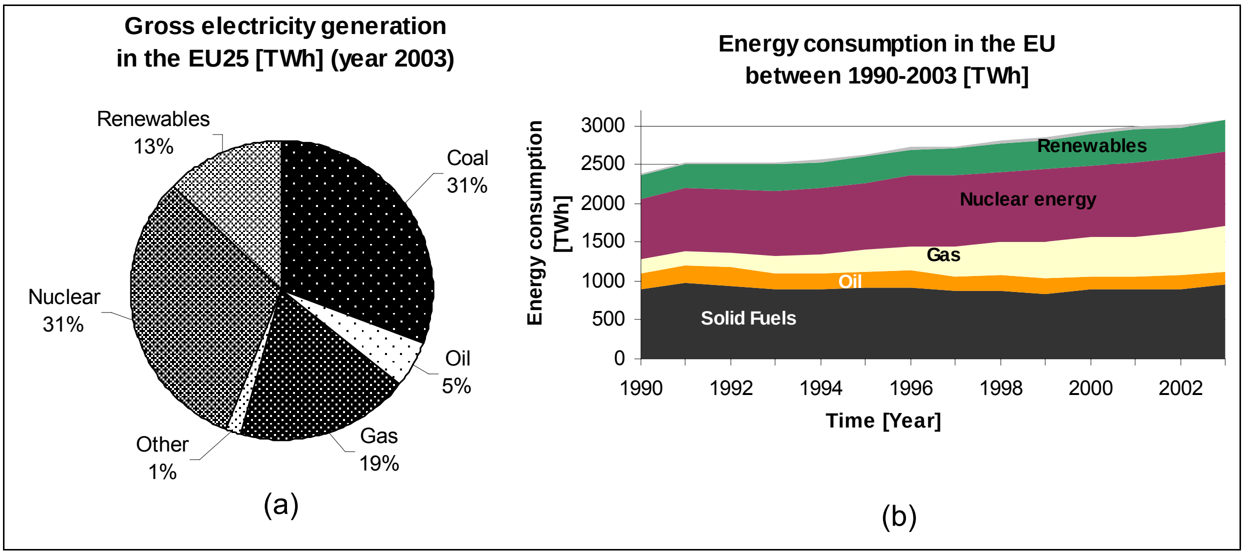

Figure 9: (a): Gross electricity generation of EU25 in year 2003 (percentage out of the total 3,121 TWh [EC,2005a]) (b): Final energy consumption in EU25 by types of sources (1990-2003) [EC,2006b]

On the other side of the energy balance stands the consumption. Generally, the share of renewable energies in EU's total energy consumption grew slightly up to 6% (Figure 9b) in the analyzed period (1990-2004). Significant increase in gas consumption can be observed whilst the use of solid fuels has been falling thereon. The households and services sectors take part with more than 40% of the total energy consumption in Europe, followed by transport with over 30% and industries with almost 30% share.

The highest share among RES in energy consumption in the EU is represented by biomass (69 Mtoe); hydropower generates around 25 Mtoe, whereas wind, solar and geothermal contribute together with 10 Mtoe (Figure 10).

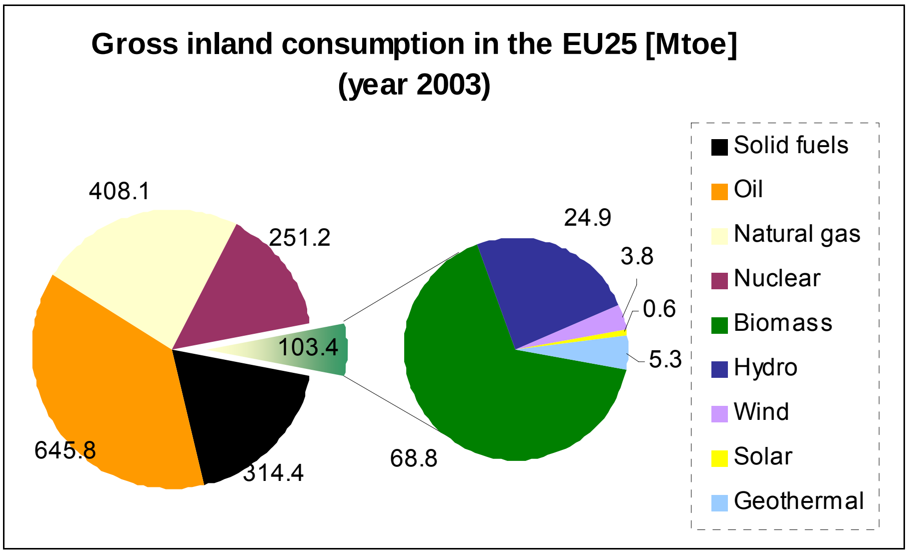

Figure 10: Energy mix of the gross inland consumption in the EU25 in year 2003 (adapted from [EC,2005a])

2.2.5.4. *Potential and future expected structure of the energy sector*

Future trends of the EU25 energy situation has been documented in various investigations; as an example, Figure 11a indicates the forecast by Taylor [Taylor,2005]. It can be seen, that the mix is henceforward dominated by fossil fuels although the consumption of solid fuels and nuclear energy show descending patterns. According to the projections, the consumption of renewables will be increasing with a growing share, but despite this pattern, the contribution of RES will not meet the indicative target by 2020 (or even by 2030) without further actions (Figure 11b).

The International Institute of Applied Systems Analysis (IIASA) contrarily predicted a possible increase of nuclear power for economic reasons rather than due to resource scarcity [IIASA,1995], which seems to be underpinning by the planned future activities around several European countries, among them Hungary [EAF,2007]. Other studies state that “nuclear power should have no role to play in Europe’s future energy mix, given the remaining risk of disastrous accidents, the unsolved problem of long-term waste storage and treatment or the devastating impacts of uranium mining. Also, nuclear power is far more expensive than alternative ways to reduce emissions” [RMI,2006]. In any case, all studies agree on future increase of RES use. Among renewables, **biomass** (including waste) is expected to have the most significant increase (from 4% share of total energy consumption to 5.2%). This can be covered by several sources, such as agricultural crop residues - 32 million tons equivalent (Mtoe) yearly, from which only 50 PJ is the actual consumption; livestock waste (17 Mtoe yearly potential), industrial sector (26 Mtoe) and forest sector (70 Mtoe) [Nikolaou,2003] (Further potential analysis of biomass can be found in Chapter 4.6.).

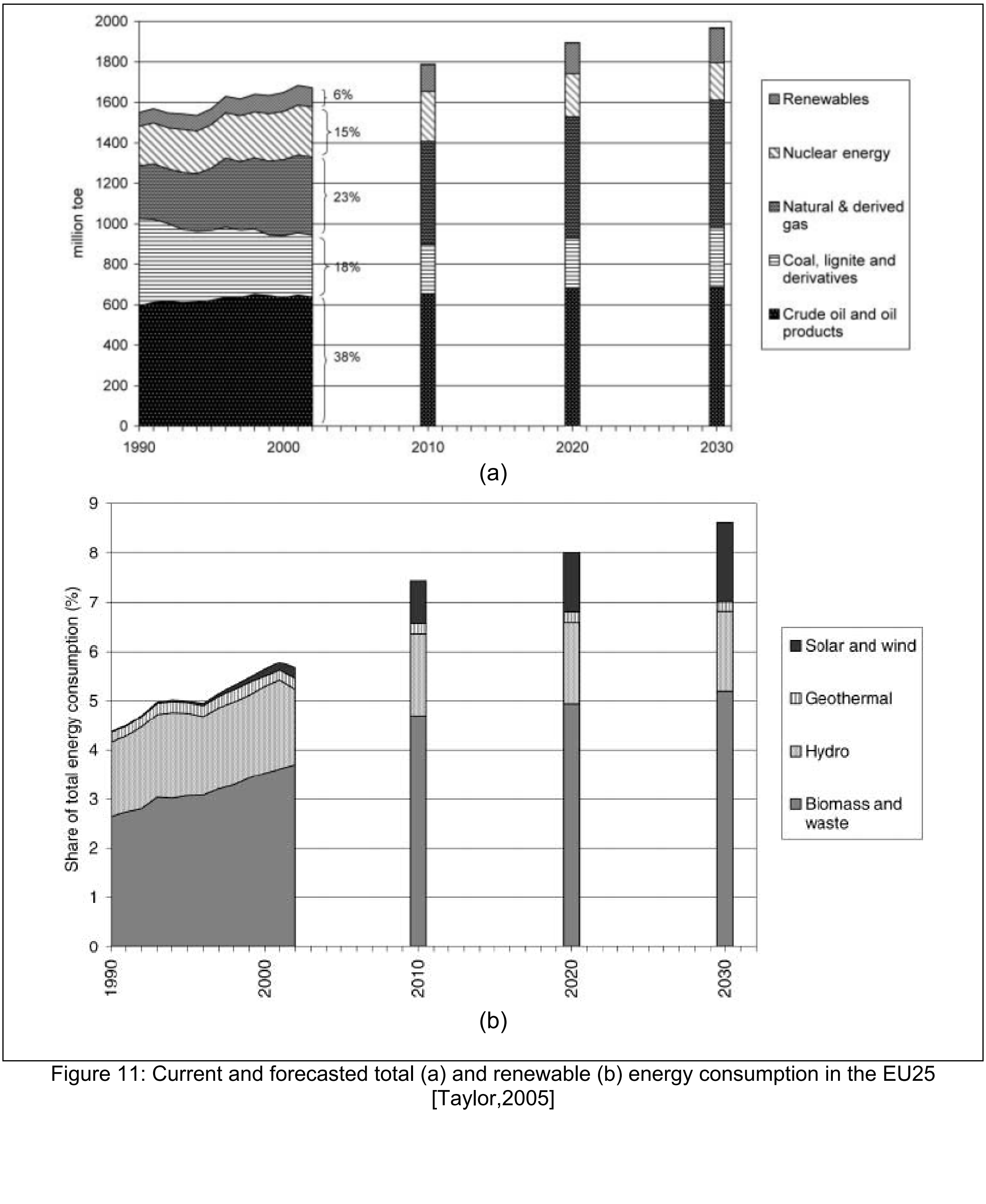

Figure 11: Current and forecasted total (a) and renewable (b) energy consumption in the EU25 [Taylor,2005]

The **solar** energy production in the EU has strongly been increasing over the last years and nowadays is over 720,000 toe [EC,2006b], [EC,2006c]. Overall, prospects for growth in the European market remain good, especially in countries where purchase prices justify PV sector investments. EC forecasts 5,000 MWe capacity for the end of the year 2010 (in comparison to 1,010 MWe in year 2004) [EC,2006b].

The existing technical and economic potential for large **hydropower** plants (above 10 MWe) in Europe has either been used, or is unavailable due to environmental constraints. In contrast to this situation, only about 20% of Europe's potential for small hydro power plants has been so far exploited [EC,1997a]. However, this realizable amount of theoretical potential must be evaluated for technical potential figures.

The progressive lifting of administrative barriers and a better understanding of national particularities on the side of developers have been very favorable elements in **wind** power market expansion. The EC forecasts upwards for 2010 with a projected installed EU capacity of 72,060 MW. The 75,000 MW objective presented by the European Wind Energy Association (EWEA) for this same date seems to be feasible and attainable insofar as current growth rates [EWEA,2007].

Even though there is a continuous increase of the use of RES, the gap between current and target indicator values for 2010 is still significant (summarized in Figure 12). A greater achievement is needed to fulfill the objective of 20 set for the year 2020 for the overall EU. According to studies, it is hardly to be matched without further strong renewable-focused policy and new support schemes in relation with research and technology development [EC,2005b]. Potential and barriers however must be analyzed at national and regional scales to find local solutions. The following section of the study introduces therefore the Hungarian situation.

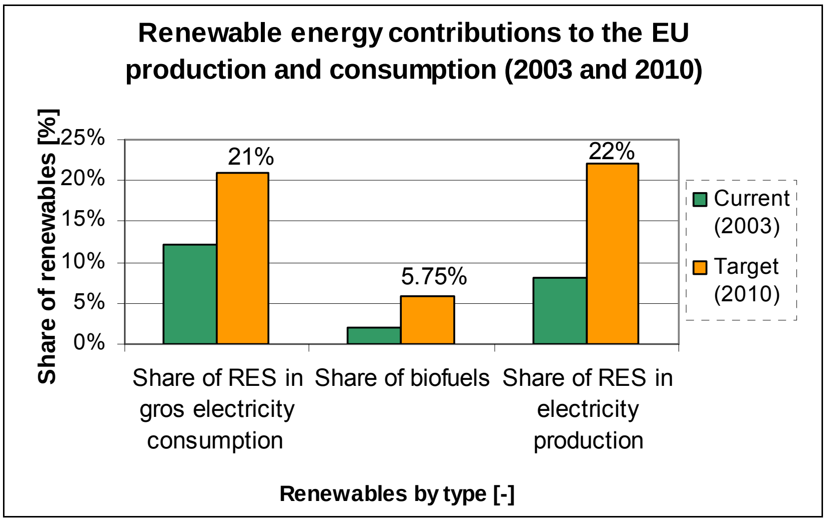

Figure 12: Current (2003) and target (2010) renewable energy indicators in the EU25 Source: [EC,2005a]

2.2.6. The Hungarian energy sector

After analyzing the European energy situation, this section describes the historical and present facts, the political objectives and national targets as well as the future perspectives of the Hungarian energy sector with its potentials and obstacles. Descriptions about endeavor to surmount the problems identified and to find sustainable solutions can be derived from the following in the form of politics and planned objectives, including figures about current and planned production and consumption of energy types by sectors as well.

2.2.6.1. Energy policy in Hungary

The energy policy is the strategy of energy supply [Matolcsy,2001]. It comprises the development of system conditions of the energy supply and energy management, the security of stable correspondence of future energy demand and possible energy sources, the elaboration of basic terms guaranteeing to fulfill the consumer protection, the environment and international undertaking, considering the conditions of economic recovery and validation of social interest. Until the beginning of the 90's, Hungary was in a unilateral and huge energy dependency situation due to the policy of the former Soviet Union (mostly eastern pipelines were built). Therefore, the main objectives after the fall of the Socialist government (1989) were to reconsider the energy politics, and to adjust it to the changing political, economic and social circumstances, to assure a higher and good quality security of supply. Based on these principles the Hungarian Government has nominated its official energy policy to [Gács,2006]:

- develop diverse energy supplies from alternative energy sources
- eliminate dependency on imports
- improve environmental protection
- increase energy efficiency through modernization of supply structures and better management of electricity consumption and
- attract foreign capital for investment in capital-intensive energy projects.

To achieve these set objectives, the country formulated its overall energy program, laws, regulations and support systems, among which there can be found green certificates, investment supports, tax immunity and return, tax allowance, and direct price support system. As first step, the energy efficiency program (1107/1999. X. 8.) was carried out in 1999 and the overall analysis on the RES situation in Hungary has been investigated since 2003 (2012/2003. I.30.). Supports of the biomass energetic use (2133/2005. VII.8.) and the green electricity underwriting price (included in the Decree 78/2005. (X.7.) GKM [GKM,2006]) have been formulated. The change of the XLII/2003 law (which allows the distribution of biogas in the natural gas system) and the endeavor to change the forest law (to facilitate energy forests plantation) can be counted among the most significant endorsements to the enhancement of Hungary's energy situation.

After Hungary's accession to the EU (in year 2004), national energy objectives have been completed with the Union's regulatory framework as well. The Hungarian Government therefore approved the national indicative target of increasing renewable electricity up to 3.6% by 2010 [EC,2001b] in line with the EU objective, which is 12%. Further increase is expected, since EU overall objective is set to 20% for 2020. The Government also undertook the promotion of the use of biofuel for transport[4] and to establish the regulatory environment for biofuels on a fully commercial basis [EC,2003]. Considering the EU's Biofuel Directive and Parliament's Decree (No. 63/2005. (VI.28.)), the indicative target is replacing 4% of the energy content of transport fuels in Hungary with biofuels (bioethanol and biodiesel) by 2010 and 10 % by 2020. Particularly bioethanol and ETBE are expected to contribute to realize this commitment [Giber,2005], with significant participation of biomass forms [EC,2006b].

Hungary's policy also participates in the climate change mitigation; a good example is that the country acceded to the Kyoto Protocol in year 2002. The national climate change strategy set the overall objective for the domestic mitigation measures below 94% of the average emission level in the base period of 1985-87 [HMEW,2005]. This objective have been reformulated in 2007, and 20% decrease of level of base year has been set for the overall EU. Hungary's current emissions are below these targets and however increasing trend in emissions is estimated in the future, emissions will not exceed the limit [HMEW,2005] (Figure 13). Even so, the country's objective is to achieve further mitigation not only due to environmental reasons, but also due to the established GHG market, which would contribute to economic growth and to attract further foreign investment.

[4] Report of the Ministry of Economy on the national plan (Governmental Resolution No. 2233/2004. (IX. 22.) and No. 42/2005. (III. 12.))

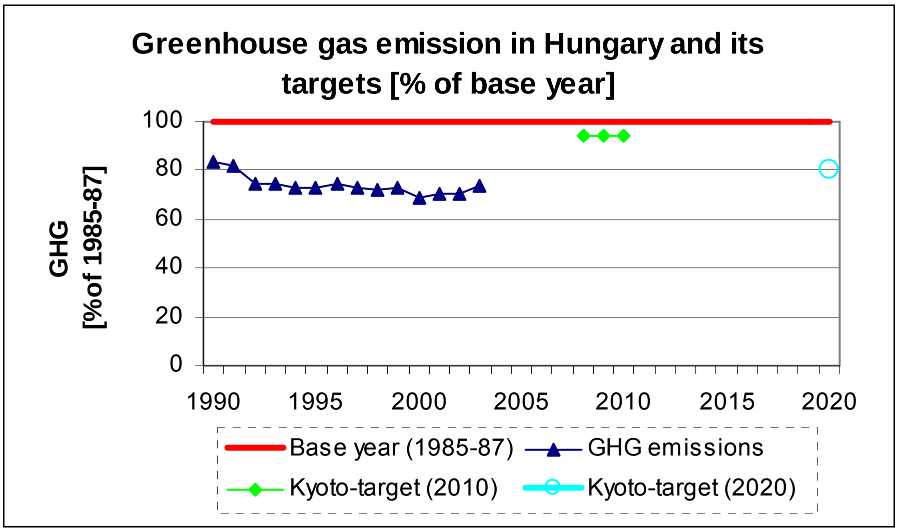

Figure 13: Historical greenhouse gas emissions in Hungary and set targets according to Kyoto Protocol [Taylor,2005]

2.2.6.2. Hungarian energy production and consumption

Energy production

Energy demand in Hungary is continuously increasing yearly in each sector, whilst extraction of fossil fuels, being the main resource, is becoming not only costly, but with more difficulties and causing higher environmentally pollution [Gács,2006]. Nowadays, the energy supply in Hungary is constant, about 1,040 PJ, but 60-70% of the resources are still imported, representing a similarly high dependency to Europe. As observed in Figure 14a, the total primary energy production of Hungary is sinking since 1990, being gas and coal production its representative examples[5]. Nuclear, oil and solid fuels exploitation also have been decreased over past years [KSH,2005a]. The electricity generation was dominated by nuclear energy and coal, which had the highest contribution in the 1990's (Figure 14b). In respect of RES, Hungary's properties in general are lagging behind those of the Member States of the EU. Nowadays, the share of renewable in electricity generation is about 10 % of the total amount of 416,000 TJ [EC,2006b], [EK,2006b], [KSH,2005a].

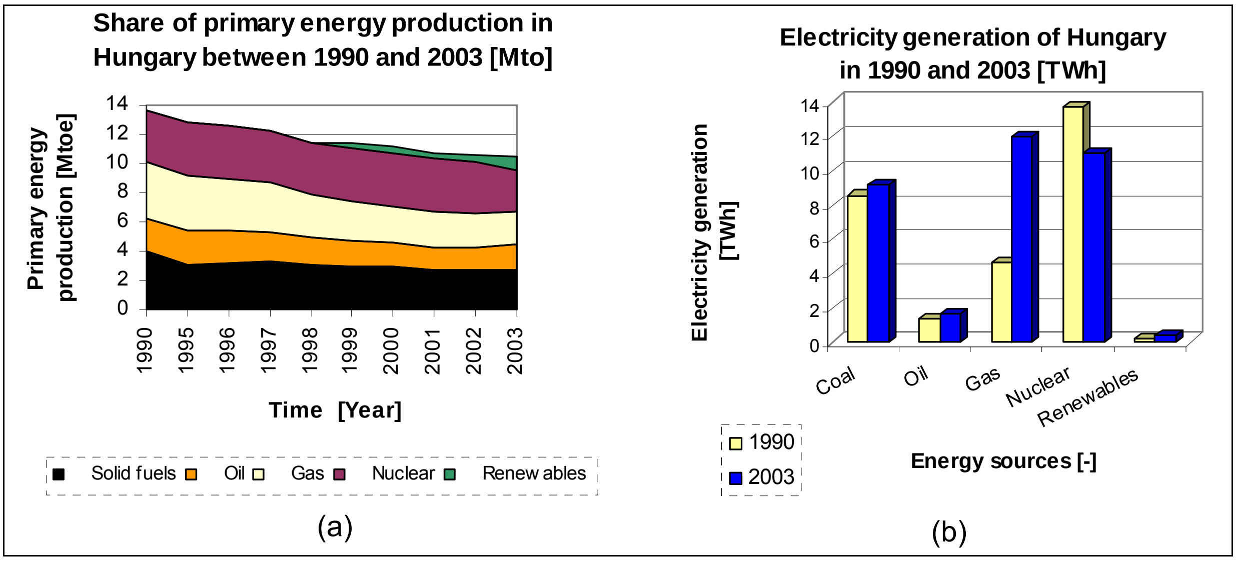

Figure 14: Share of primary energy production (a) and electricity generation (b) in Hungary between 1990 and 2003 (Sources: [EC,2006b], [KSH,2005a])

[5] In 2003, the total gas production corresponded only to 60% of the production achieved during the 1990's.

As main renewable sources, hydropower and biomass contributed the most to electricity generation; until 2004, wind power had still a very low share (~0.1%). Table 4 summarizes the development of the share of renewables in electricity production and heat use in Hungary between 2001 and 2004. Hungary's greatest opportunities lie in the utilization of biomass-based energy (including biofuels for transport, biogas from agriculture, municipal biodegradable waste and wood-based biomass [Bai,2005]) and geothermal energy, but there has been a favorable shift in the field of using wind and solar energy over the recent period.

Table 4: Energy production based on renewables in Hungary (2001-2004) (Source: [Bai,2005])

	Electricity production (GWh)				**Heat utilization (TJ)**			
	2001	**2002**	**2003**	**2004**	**2001**	**2002**	**2003**	**2004**
Geothermal	-	-	-	-	3,600	3,600	3,600	3,600
Solar collector	-	-	-	-	60	70	76	76
Firewood	7	6	109		13,539	14,592	18,176	23,900
Forest waste	-	-	-	793	4,600	4,550	4,800	15,029
Other biomass	-	-	-		12,461	11,602	9,625	
Biogas	7,6	11,2	18,37	23	126	133	191	229
Water energy	186	194	171	210	669.6	698.4	615.6	756
Wind energy	0,9	1,2	3,6	5,5	3,24	4,32	12,96	20
Other	0.06	0.06	0.07	0.1	0.0216	0.0216	0.0252	0.36
Sum	*201.5*	*212.4*	*301.97*	*1031.6*	*35.1 PJ*	*35.2 PJ*	*37.1 PJ*	*42.7 PJ*
Waste combustion	112	59	67	54	2,597	1,995	1,507	1,373
Total	***313.5***	***271.4***	***368.97***	***1,089.6***	***3.,7 PJ***	***37.2 PJ***	***37.6 PJ***	***44.1 PJ***
Share (%)	0.8	0.6	0.9	2.6	3.6	3.6	3.5	4.2

Energy consumption

The total annual energy consumption in Hungary is more or less stable at about 25-28 Mtoe yearly. Households participate the most in the consumption (37%), whilst industry and transport have also a high contribution, averaging one fifth of the total, shown in Figure 15.

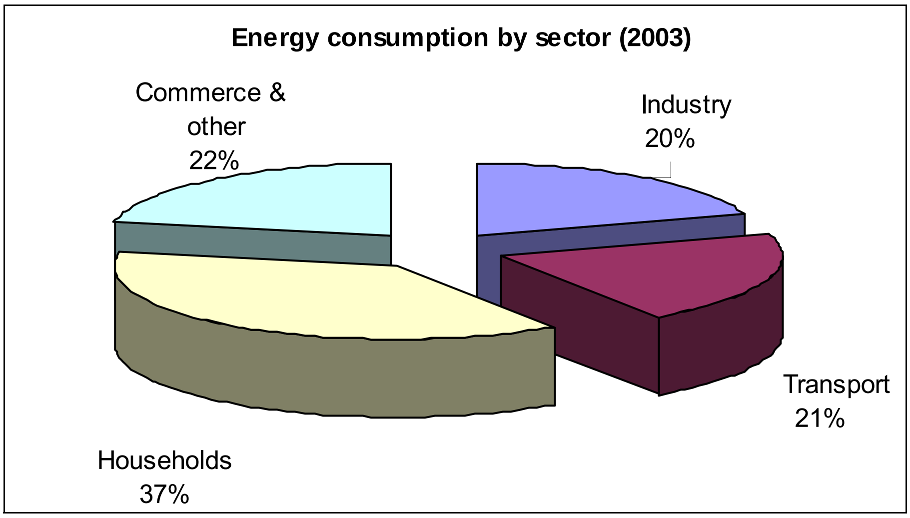

Figure 15: Overview of the sectoral energy consumption in Hungary in the year 2003 (Source: [KSH,2005a])

Permanent and dynamic energy consumption growth in the transport sector is expected to continue as incomes rise. A continuous increase is also probable in the energy consumption of the residential sector as well as in the industrial sector. It has to be noticed that this increase of energy consumption, coupled with a decreasing production, could only be afforded with significant import of energy. In previous years, the dependence of the country on energy imports was rated at 65-73% (Figure 17), which dependence is expected to grow in the next few years, without using other alternative energy sources. The national energy balance for the year 2004 is included in Annex III.

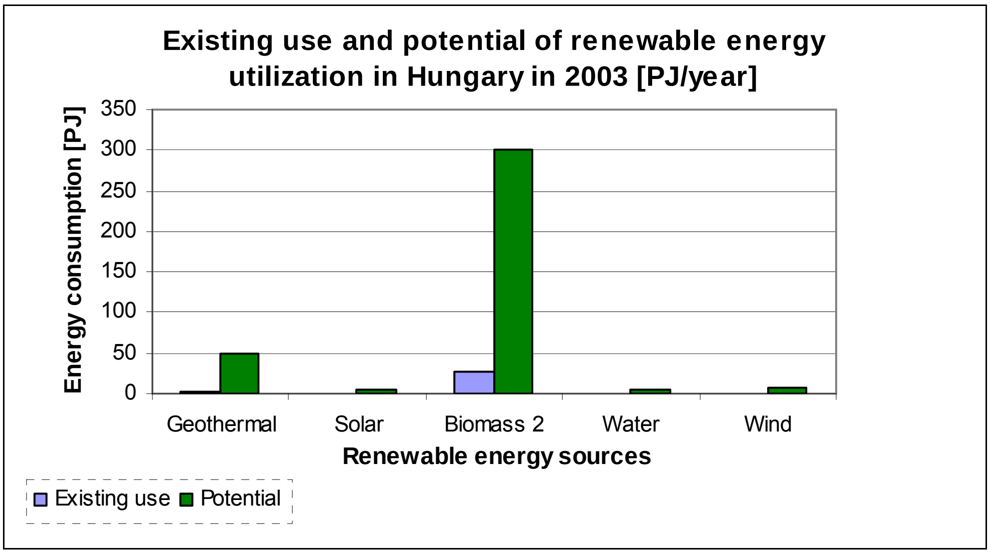

Figure 16: Overview of the current and potential of renewables at national level in Hungary [Marosvölgyi,2000]

Renewable energies in Hungary

As observed in Figure 17, The Hungarian renewable energy consumption in 2004 was 39,000 TJ, which is about 3.6% of the total energy consumption [GKM,2006]. Although use of RES is increasing yearly, there is still a huge difference between the potential and use [Marosvölgyi,2000], presented in Figure 16.

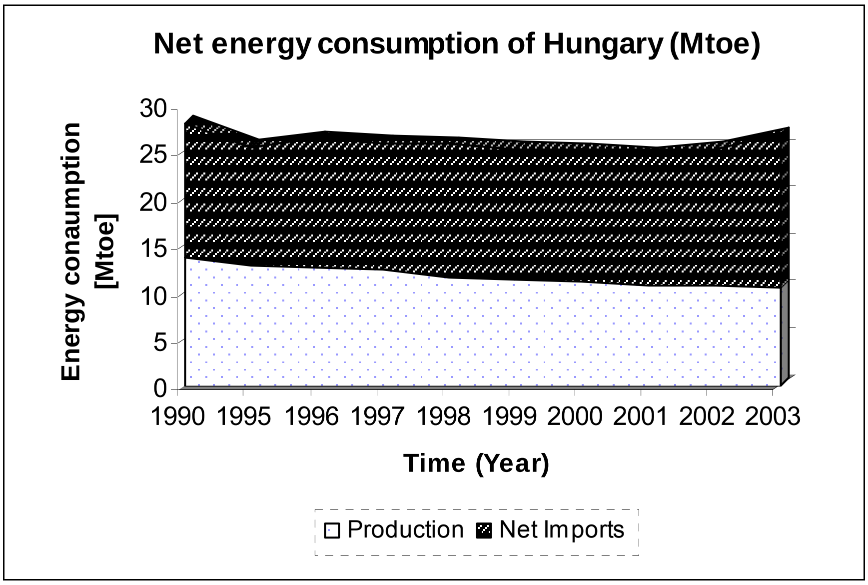

Figure 17: Evolution of the total energy consumption in Hungary (1990-2003) (Source: [EC,2005a])

Until the end of the 19th century, when more than 22,000 **water**-wheels and turbines were running, hydropower was one of the most important energy sources (especially in the mill industry) in Hungary. Many of them have been dismantled and/or abandoned [Stumphauser,2005b], but partially have also been converted into hydroelectric power plants: currently, 37 plants are running with a sum of 150 GWh power energy production yearly [Gööz,2006], [Schmidt,1998].

The Hungarian **wind** conditions are only partially known, and measurements have been performed mostly in the altitude of 30-50 m. The wind energy potential in the middle and southeastern part of the country is 70W/m² and 160-180W/m² in north-west of the country. As result of the investment supports and the compulsory reception of power energy produced from renewables, the process of wind plants-building has been started [Giber,2005]. Furthermore the spread of wind plants has been promoted as the environmental aspects of their establishments have been collected and documented [KVM,2004]. Currently 10 wind power plants are running in Hungary generating 5.6 GWh power generation and 20 TJ heat yearly.

In Hungary the conditions for **solar** energy utilization are most favorable in the regions characterized by high duration of solar radiation. Due to the energy efficiency programs in Hungary, several solar collector systems have been built for private or industrial purpose. Furthermore the Directive 2002/91/EC [EC,2002] accelerated the use of solar energy, since it specifies that “for new buildings with a total useful floor area over 1,000 m², Member States shall ensure the technical, environmental and economic feasibility of alternative systems”.

Hungary has favorable **geothermal** conditions, since its geothermal gradient is 5°C/100 m, which is about one and a half times as high as the worldwide average [EK,2001]. The reason is that in the Pannonian basin, including also Hungary, the earth’s crust is relatively thin, resulting in a temperature of 60°C at the depth of 1,000 m, and 110°C in 2,000 deep. The measured value of heat-flux is also rather high: the average is 90.4 mW/m² (the mean value in the European continent is 60 mW/ m²). Taken into consideration the possible environmental impacts and technological capacities, there is a yearly 10-50 PJ theoretical geothermal potential, from which currently only 3.6 PJ is the effective use. This low production is basically due to the extensive production, the low quality technology, the lack of sufficient measurements, reinjections and the unadjusted proprietary rights [Stumphauser,2005c].

The produced **biomass** in Hungary is a dominant factor in the renewable energy structure. The natural conditions put Hungary in a very favorable position and let solid biofuels play an important future role in the country’s energy supply system. Use of biomass for energy purposes represents a great alternative to renew the Hungarian agriculture in regards to the land-use, and to grow the rural employment [Marosvölgyi,2005b]. Conditions for generating energy from biomass have been established in the Hungarian legislative and support framework, as previously introduced. Besides, there are schemes influencing the use of RES, which do not directly have reference to the energy sector, but to their sources, e.g. agriculture and forestry. A good example for that is the 86/2004. (V. 15.) FVM Decree [FVM,2004c] in accordance with the European Agricultural Guarantee and Guidance Fund and Common Agricultural Policy (CAP) objectives, comprising among others the Single Area Payment Scheme (SAPS). It involves the payment of uniform amounts per eligible hectare of agricultural land, up to a national ceiling laid down in the Accession Agreements. Considering that SAPS does not depend on the purpose of the agricultural products, it can also be received for energetic crops produced with arable conditions, which are set in the 4/2004. (I. 13.) FVM Decree [FVM,2004b]. The national top-up covers a 44-49,000 Ft/ha contribution to the establishment of energetic plantation, depending on their types, as defined in the Decree of 74/2005 (VIII.22) FVM [FVM,2005]. Moreover, the 131/2004. (IX.11.) FVM Decree [FVM,2007] defines special conditions for supporting areas with unfavorable conditions.

Firewood has the highest share among biomass sources in Hungary, whilst wastes contribute the most to the heat consumption. In general, the obstacles for the spread of renewables (biomass) use are the wide scale installed gas-system, the incomplete/not reliable information, the expense of new technologies, the few experience, the deficient legislative and institutional framework and the lack of sufficient support programs [Westergrad,2002].

The national energy policy provides assistance in implementing biomass installations, but there are still obstructive parts in the legislation. The realization of set objectives also requires large capital and financial supports, the lack of which can be another barrier for the utilization of RES. As the current situation of solid biofuels is at on initial stage in Hungary, there is no regulated trade and logistic system, no respecting quality management. Establishment of these systems is becoming a most important task. To surmount these obstacles and to spread the use of RES, a significant investment support is required. The Environmental Infrastructure and Operative Programmes (EIOP) contributed to the construction of biomass based plants with maximum 40%, or max 1,209,433 Euro. Incentive is the electricity underwriting price in

Hungary as well; which has gone through changes since its issue (2005). In 2005 the yearly underwriting prices was 21,008 Eur/TJ for renewables independent from the weather (GKM Decrees of 2/2005. (I.13.) and 9/2005. (I.21.) [Bohoczky,2005]). In 2006 the underwriting price of power energy produced from biomass is 23.27 Ft/kWh (26,059 Eur/TJ) according to the 112/2005. (XII. 23.) GKM Decree. Further possibilities to contribute to RES use are dissemination related to utilization of renewables, as well as development of know-how and methodologies for dynamic analysis of complex effects [MET,2003].

After analyzing the energy sector, its definitions, features, main components, as well as the European and Hungarian historical situation, future plans and advantages and obstacles of development, the initial questions of this study can be posed again: which kind of alternative could be applied for future production and use of energy forms within a region as a complex contributing to its sustainable development? Which decisions should be taken and how could it be supported to make such? To be able to answer these questions, first the theories and applications of various decision making tools and systems are introduced to understand possible ways of making such decisions in a scientific way.

2.3. Decision making theory and applications

Summarizing the conclusions drawn from described in previous chapters, production and use of RES is a future goal, plan and interest of European countries, among them Hungary. But to make decision regarding the kind and amount of RES, the field, in which it is used, the circumstances of its application, and the spatial and temporal extensions, all system components should be analyzed at regional level. Formulated local alternatives must suit the international and national targets, and incorporate at the same time the overall SD approach as well. To take successful decisions in the field in study, the definition, summary and characterization of decision making (DM) and its possible tools is viewed below.

2.3.1. Theory and application of decision making

The world consists of a network of complex interrelated and interacting components with their causes and effects, formulating problems as well. To solve these problems and to make convenient decisions has been a reflection of many thinkers since ancient times: the philosophers Aristotle and Plato already discussed the human capacity to decide. Decision making (DM) is a cognitive process leading to the selection of a course of action among alternatives, where an alternative can be defined, as one of several options which can be chosen to achieve the desired goal. Every decision making process produces a final choice called decision (or a series of decisions).

There are two principle ways to analyze casual influences: one is the traditional linear deductive logic, which begins with assumptions and obtains several conclusions and deducts an outcome from them. The other one is a holistic approach, involving all factors and criteria, and all possible outcomes are joined together in the system. Applying knowledge and experiment, the relative influence and the overall answer are derived [Saaty,2006b]. Deductive thinking concerning complex problems often does not allow to identify nor to solve the complex interrelated problems [Saaty,2006a], but breaking down a problem into its constituent components and studying their behavior have been proven successful in several fields of DM. Many important technical aspects of DM are linked to the classical decision theory developers. As an example, Gregory and Clemen [Gregory,1994] lay out eight themes as elements of good decision making, as seen in Figure 18. These themes represent the fundamental principles of decision analysis and reflect its consistent approach, including many procedures, methods and tools. The first step of any decision making - according to [Gregory,1994] - is establishing the decision context and identifying the key players in the decision process, through identifying relevant stakeholders (person or body with an interest in the decision under consideration).

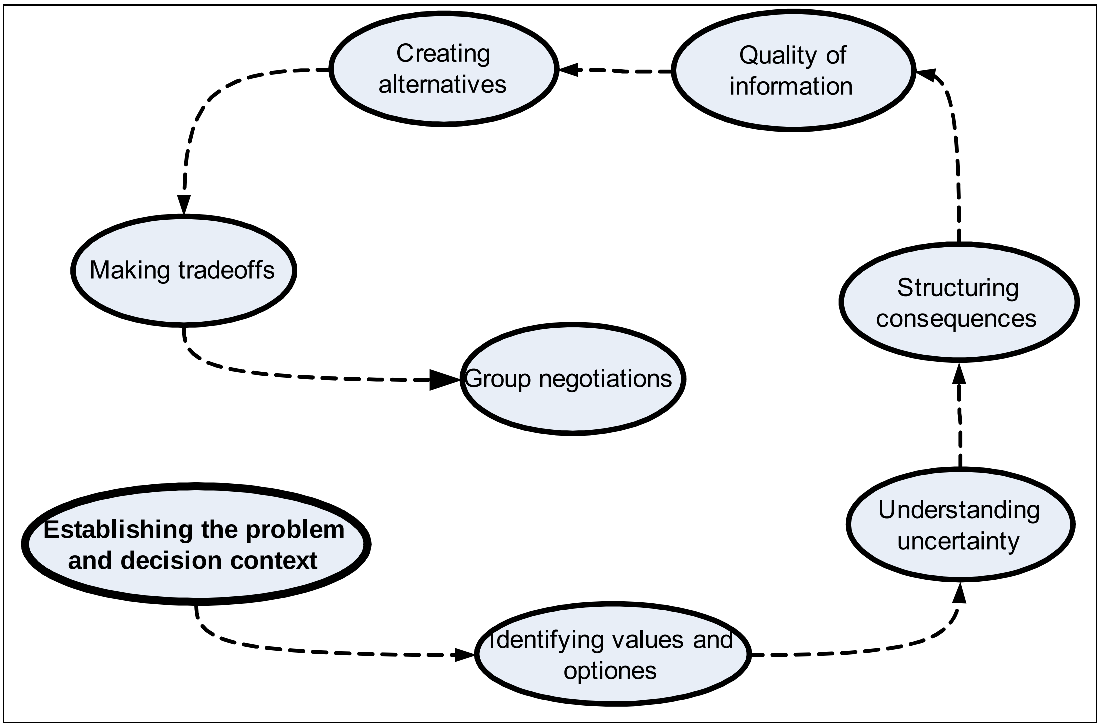

Figure 18: Decision making themes according to adapted from [Gregory,1994]

Recognition of the problems and the decision opportunity, as well as the reasons of the decision's importance are the next activities to be performed, with the involvement of established stakeholders [Clemen,1994]. All decision making activities bring intrinsically a set of alternatives possible to be conducted in a given situation, from which a decision must be made. Decision is made then by a decision-maker, who is a person, organization or any other decision making entity, which is empowered to make decisions concerning the identified problems and objectives at hand. In most cases the decision maker is also responsible for the decision and possible consequences. Decision making can be done individually [Saaty,2006a], but when DM implies several sectors, individual knowledge and experience might be inadequate, because discussion and exchange is needed to reach a consensus on details of problems and objectives. Additional assessment should always be performed to identify the range of values for uncertain components of the system. Following up the classical DM theory, an analytical and management tool is the Logical Framework Approach (LFA) [EC,1999b], [AUSGuidelines,2003], which includes logical structuring of problems and derived objectives. LFA than evaluates the objectives' contribution to the identified main goal via assessing them quantitatively when applying various scenarios. LFA consists of two main phases: analysis and planning phases. the former consisting of the stakeholder-, problem- and objective analysis, and the latter of the definition of intervention logic and specification of assumptions and risks among others. However, LFA alone is not considered as DM tool, therefore it requires a complement of other methods (e.g. definition of vision, SWOT analysis) resulting in a more comprehensive tool-set. In the forthcoming sections, the steps of LFA related to establishing a DM framework are described, complemented with other methods, namely the stakeholder analysis, SWOT, objectives identification and assessment of indicators.

2.3.1.1. From problems to objectives

For an adequate decision making within a certain region first the region itself must be studied. It involves the performance of complex historical analysis, identification of main problems and factors hindering a desired development and derivation of specific objectives in accordance with local stakeholders. When applying various alternatives, assessment of quantitative achievements toward objectives support decision making. Based on the above, the sequence of investigation proposed to develop a decision making tool-set at regional level is summarized in Figure 19).

The process, as described before, starts with detailed investigation about the **regional** past and present situation. Afterwards the negative components and **problems** must be identified in order to understand why any change of the situation is required and in which sector.

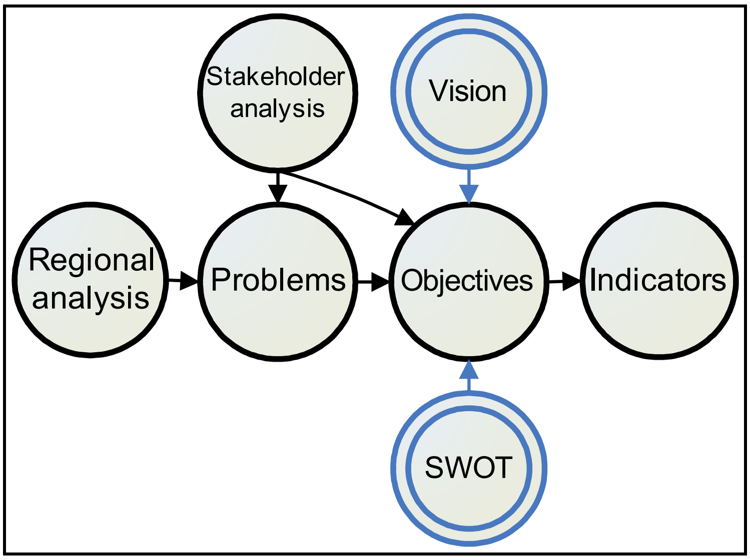

Figure 19: Sequence of determining regional indicators

Problems are complex and interrelated; besides, they contain both tangible and intangible components [Meadows,1972]. Problem identification also requires the involvement of **stakeholders**, who should be involved in the decision making process from the beginning of the work. Generally, stakeholder involvement can be classified in different levels according to the degree of participation. For example, the International Association for Public Participation (IAP2) provides a framework for planning public participation processes, with five levels (see *Figure 20*). The level of public impact is increasing in the following sequence, from what each includes various stakeholders entities [IAP2,2006]:

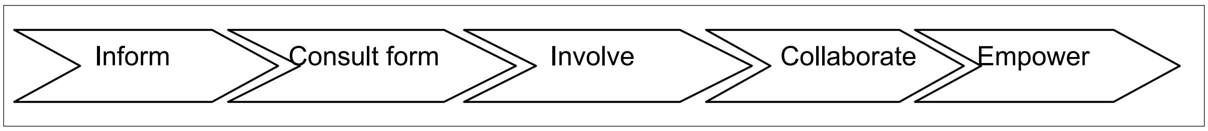

Figure 20: Level of public impacts of stakeholders involvement

Benefits of partnerships are the shared vision of local, regional, national and even cross-border or global level, the strategic thinking, the co-ordinated actions that can influence other decision-making bodies and initiation of further common activities. Besides, it allows knowledge, data and information transfer, it fosters skill development and synergies of better links between public agencies, private and business sector and other participants in the local economy [MUL,2005].

Stakeholders can contribute not only to identifying problems but also to establish a further strategic planning tool used to evaluate a **SWOT** analysis [EC,1999a]. This technique is probably originated from Albert Humphrey, leader of a research project at Stanford University carried out in the 1960s. During the 1980s, public administration applied this classical model of strategic planning, adopting the basic managerial model across such areas as regional development and municipal planning [Karppi,2001]. The SWOT analysis approach seeks to address the question of strategy formation from a two-fold perspective: from an *internal* appraisal (of Strengths and Weaknesses) and from an *external* appraisal (of Threats and Opportunities). The two perspectives can be differentiated by the various degrees of control attainable within each. The dynamic and unrestricted nature of the external environment can seriously hamper the process of detailed strategic planning, whilst internal factors are more easily manageable. The four elements of a SWOT analysis undertaken as part of a wider strategic planning are presented in Table *5*.

Table 5: The elements of SWOT analysis

Element	Description
Strength	resource or capacity the region can use effectively to achieve its objectives
Weakness	limitation, fault or defect in the region that will keep it from achieving its objectives
Opportunity	any favorable situation in the region's environment
Threat	any unfavorable situation in the region's environment that is potentially damaging to its strategy

The actions to be taken that can be deduced from these four elements are: (1) use and building on strengths, (2) reduce or eliminate weaknesses, (3) take advantages of opportunities and (4) mitigate the effect of threats or defend against them [Dealtry,1992]. Within regional circumstances the SWOT instrument is intended to highlight the dominant and determining factors, both within and outside of the territory under study, which are likely to influence the success of identified alternatives [EC,1999a]. Consequences drawn from problems identified, results of SWOT and further contribution of stakeholders endorse the definition of the overall **vision** of the region under study. Vision can be defined as a short description of the desired situation to be achieved in the future. On the other hand, a main goal can be formulated from this vision, which can be broken down into specific **objectives**, in consonance with the specific problems (or derived from them). Definition of objectives includes not only the knowledge gathered through regional and problem analysis, SWOT, and vision, but also the involvement of local and regional players is needed.

For a hierarchical and logical objective structuring and analysis, two main approaches can be used, namely: (1) the 'focal problem' method, where a group brainstorms problems, than a focal problem is identified, and finally the cause and effect analysis pivots around the focal problem, or (2) the 'objectives oriented' method, where a goal is specified at the start of the analysis, and constraints to achieving it are then identified, analyzed and sorted into a cause and effect logic. A goal is directed towards a vision and consistent with the achievable future image; an objective, in turn, is a specific, measurable result expected within a particular time period, consistent with a goal and strategy [AUSGuidelines,2003]. A graphical representation of both is observed in Figure 21. Both methods described are equally valid, and which to use is largely up to individual preference and circumstances and the purpose of the analysis.

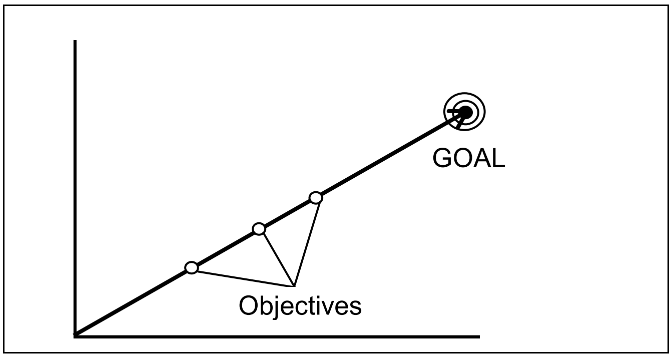

Figure 21: Graphical representation of a goal and its objectives

For structuring goal systems, there are two common schemes of information processing:

1. The 'top-down' (TD) approach emphasizes planning and a complete analytical understanding of the systems as it is necessary in decision support. A top-down approach starts from the most general objective, which is then successively divided into sub-objectives [Hämäläinen,2002]. An example of this is the Top-down Object-based Goal-oriented Approach (TOGA), a conceptual framework developed by Gadomski [Gadomski,1994].
2. The 'bottom-up' (BU) procedure is a very participative process of analysis work and supports fundamentally future acceptance of planning results and motivates accordant future actions in the region. BU procedure overlooks broad and/or global systems and instead focuses on the bottom of the system, e.g. individual attributes of regional components. In a BU approach, all meaningful differences between alternatives are first listed and then combined and structured to higher level objectives.

By combining both methods in an appropriate way, the contribution to multi-achievements can be ensured, matching exact regional demands (BU) and at the same time contributing to overall system's achievements (TD). A representation of a simplified hierarchical objective tree is designed in Figure 22 and the Ishikawa or Fishbone diagram [Ishikawa,1985], represented in Figure 23. According to the Australian Government Guidelines [AUSGuidelines,2003] an objective system must satisfy at least the properties of completeness (all relevant objectives should be included in the hierarchy) and operationality (objectives and indicators should be meaningful and assessable).

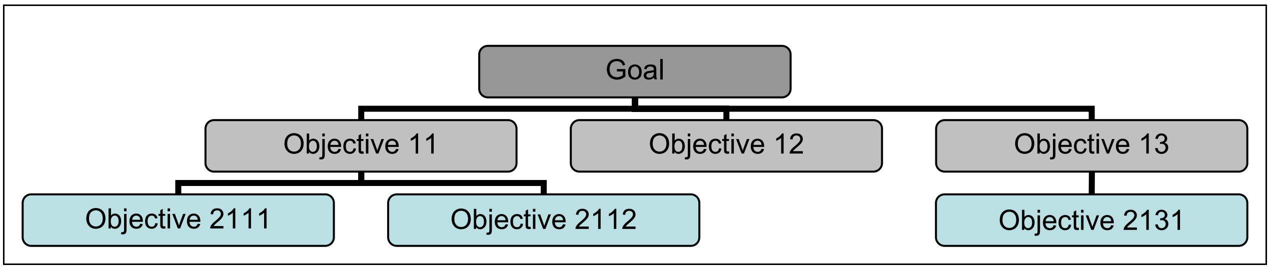

Figure 22: Principal structure of an objective tree
Comment: Objective 1x: Level 1 objectives; Objective 2x: Level 2 objectives

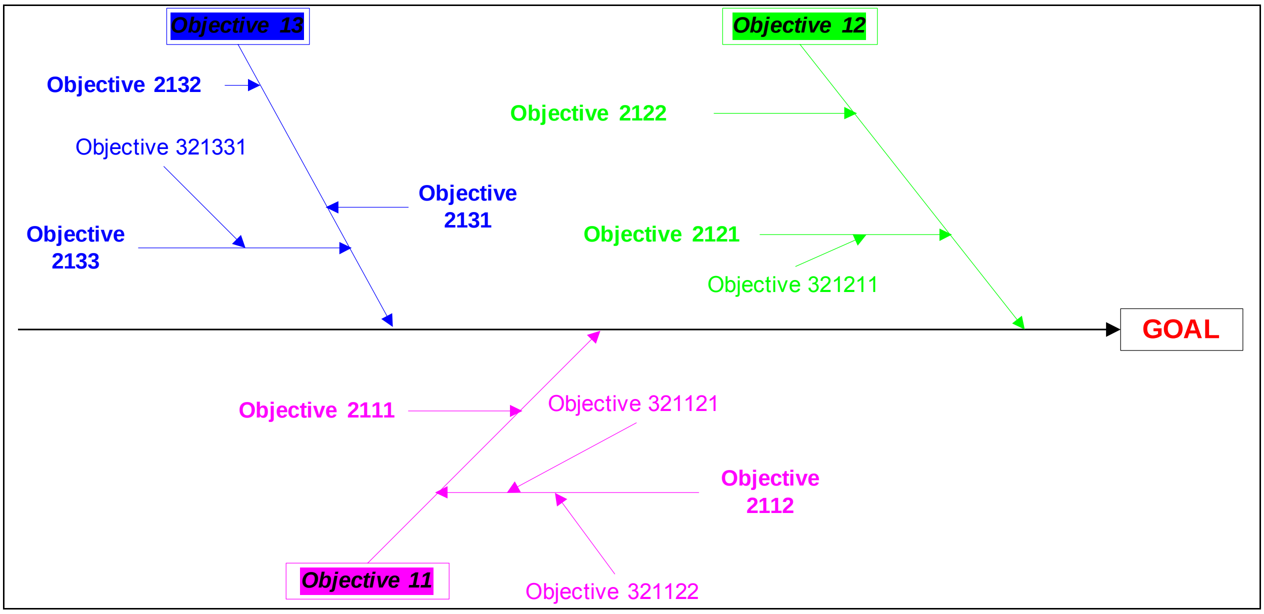

Figure 23: Ishikawa or Fishbone diagram of a goal system

However, an objective tree can include various levels and interacting subsystems ordered in a hierarchic fashion, such as the multilevel-multigoal system [Wezel,2001]. Hierarchical structures can be represented with the Analytic Hierarchy Process (AHP) method [Saaty,1980]. 'AHP is a framework of logic and problem-solving that spans the spectrum from instant awareness to fully integrated consciousness by organizing perceptions, feelings, judgment and memory into a hierarchy of forces that influence decision results' [Saaty,2006a]. The AHP is based on the innate human ability to use information and experience to estimate relative magnitudes through paired comparisons. These comparisons are used to construct ratio scales on a variety of dimensions both tangible and intangible. Arranging these dimensions in a hierarchic structure allows a systematic procedure to organize the basic reasoning and intuition by breaking down an objective into its smaller constituent parts. The AHP thus leads from simple pairwise comparison judgments to the priorities in the hierarchy (see Chapter 5.5.2 also).

Many decision problems and objectives cannot be structured hierarchically because they involve interactions and dependences of higher-level elements on lower-level elements. Hence, the components constitute a network, which spreads out in all directions and involves cycles between levels, and even between components in one level [Saaty,2006b]. Such feedback structure does not have the linear top-down form of a hierarchy, but looks more like a network, with cycles connecting its components and with loops connecting a component to itself. A new and innovative achievement on multicriteria decision making developed by Saaty [Saaty,2006b] applies network structures with dependence and feedback to complex decision making. The resulted Analytic Network Process (ANP) is a methodological tool that is helpful to organize knowledge and thinking, elicit and quantify judgments registered in both in memory and in feelings, derive priorities from them, and finally synthesize these diverse priorities into a single mathematically and logically justifiable overall outcome. In the process of deriving this outcome, the ANP also allows for the representation and synthesis of diverse opinions in the midst of discussion and debate. The ANP approach is also based on absolute scales used to represent pairwise comparison judgments in the context of dominance with respect to a property shared by the homogeneous elements being compared. The scales are converted into numbers validated and extended to inhomogeneous elements. The main development of ANP when comparing to AHP is, that it represents network systems, instead of hierarchies.

2.3.1.2. Indicators

In any system simply stating an objective is not sufficient: it is important to establish ways of measuring the objectives and progress achieved in order to ensure the appropriate conduction or application of alternatives regarding the objective under assessment. To ensure that an objective is measurable it must be accompanied by indicators which specify the required information.

According to the Australian Government Guidelines, indicators „refer to the information we need to determine progress towards meeting stated project objectives" [AUSGuidelines,2003]. The European Observatory [LEADER,1999] further classifies indicators as ones responsible for current or growth development. Following the 'SMART' characteristics might result in appropriate indicators, which must be:

- **S**pecific to the objective, so that any progress towards the objective can be attributed to the defined alternative and not to some other cause.
- **M**easurable at acceptable costs and with acceptable efforts.
- **A**ttainable with reasonable appropriate collection methods.
- **R**elevant to the management information needs[6].
- **T**imely **-** an indicator must be collected and reported at the right time (period).

Furthermore indicators should be reliable, real and easy to understand. An indicator should provide, where possible, a clearly defined unit of measurement and a target detailing the quantity, quality and timing of expected results. The steps involved in the selection of indicators within a classical LFA method are provided in Figure 24.

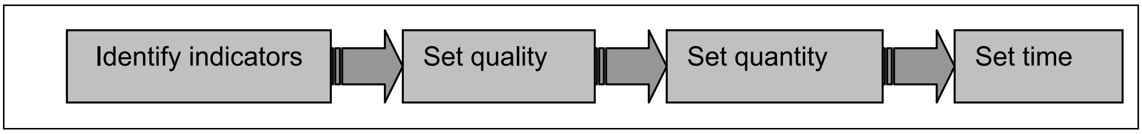

Figure 24: Steps involved for selection of indicators in the Logical Framework Approach

When indicators are formulated, the source of information and means of their collection and process should be specified. This will help to test whether or not the indicator can be realistically measured at the expense of a reasonable amount of time, money and effort. Therefore, sources used to define and formulate indicators have to be official statistics, databases or other reliable references.

A further concept of indicators is the widely used Pressure-State-Response (PSR) Framework [OECD,1993]. Basically a *pressure* is any human activity on the environment, which can induce changes in the *state* of the environment. Society then *responds* to changes and policies or other activities, intended to prevent, reduce or mitigate pressures and/or environmental

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[6] Information must be sorted, screened, aggregated and summarized in different ways to meet different needs.

damages. This framework has formed the basis for ongoing developments of the Driving Force-State-Response (DSR) and the Driving Force-Pressure-State-Impact-Response (DPSIR) frameworks, both of which are still under development.

Various fields of science and research have identified their own specific indicator sets, such as for example the ‚Environmental Indicators for Agriculture', 'Core set of Indicators for environmental performance reviews' [OECD,1993], Energy, Transport and Environment Indicators' from the EC [EC,2004a], Indicators of Sustainable Development of the UN [United Nations,2001], etc. However, for each case study a uniquely developed indicator set can be developed with both overall and specific indicators.

2.3.1.3. Weighting methods

In the practice, the introduced objectives and indicators can be identified and set according to the above described principles. But certainly not all objectives can be taken into consideration with the same relevance. The quantitative differentiations of objectives' importance must therefore be represented within the system, to be able to measure their **weights** and the share of their contribution to the achievement of the main goal.

Preferences can be set personally or in a group, which can be defined by stakeholders, decision makers or specialists from the related field of science. In most cases the preference elicitation is an iterative process in which several different methods might be used. According to [Hämäläinen,2002] there are two ways to determine weights in an objective tree, namely non-hierarchical method, where weights are defined for the indicators, and hierarchical method in which weights are determined for each hierarchical level separately, and then multiplied to get the corresponding lower level weights. In the following section possible selected weight elicitation methods are introduced being appropriate for defining preferences for both indicators and objectives.

1. *Expert judgment* (e.g. Delphi) methods are based on a structured process for collecting and using knowledge from a group of experts by means of a series of questionnaires and with controlled opinion feedbacks [Dalkey,1969]. These elicitation methods require experts from each sector involving the objective system, but being intuitive, it does not apply any further analytic method. Intuitive decisions are not supported by data and documentation and therefore may appear arbitrary.
2. In *rank-based methods* the decision maker defines the ranking of objectives or indicators. The weights are then calculated by using the mathematical formulae that implies the same order. Methods are simple and do not require much from the decision maker, therefore they are ideal for a preliminary screening of alternatives. However, the shortage of this approach is that only information on the ranking order of the attributes is used and there are likely to be several weightings implying the same order. As examples the SMARTER, Rank exponent or Rank reciprocal methods can be named [Hämäläinen,2002].
3. The *ratio based methods* use ratio scales in preference judgments. The Simple Multi Attribute Rating Technique (SMART) [Edwards,1977], Rank Inclusion in Criteria Hierarchies (RICH) and pairwise comparison of AHP are examples of this group. AHP is based on paired comparisons, on the use of ratio scales in preference judgments and on consistency of judgment as well. It is built on the innate human ability using information and experience to estimate relative magnitudes through paired comparisons [Saaty,1980], [Saaty,2005].

The elicitation of precisely specified objectives' weights may be difficult due to the urgency of the decision, lack of resources for completing the elicitation process, or conceptual difficulties in the interpretation of intangible objectives [Wolfbauer,2005]. Any weighting method must fulfill several criteria for being selected. Among others it must be:

- simple in construction and robust
- adaptable for group and individual DM
- must represent a concept beyond intuition
- must be able to quantitatively assess resulted weights
- both hard and soft data must be evaluable with the method

Considering the above, AHP is appearing suitable for weighting regional objectives evaluation including hard and soft data. AHP can be adjusted and set according to individuals' set, and represents a functional and methodological tool. It is a simple and robust method, resulting in quantitative weights of defined objectives and indicators. The general steps of AHP, as well as its application are presented in Chapter 5.5.2.

2.3.1.4. Indicator calibration

Indicators identified and weighted must also be normalized against their subjective utility functions [Wolfbauer,2005], [Händle,1974]. That is the process of transferring their absolute values set with units of measurement into scores (for example between 1 and 10). To define preferences in such way, utility functions for each indicator must be established individually, according to its nature, role, and current and desired values. Figure 25 shows an example of this transformation, representing diminishing marginal utility, according to Gossen's First Law [Gossen,1854]. However, the increase of one further unit can bring to a "tipping point", which might result in increasing marginal utility as well. In the abscissa of Figure 25 there are the real possible values an indicator can take and in the ordinate can be red the related preferences as scores from 1 to 10.

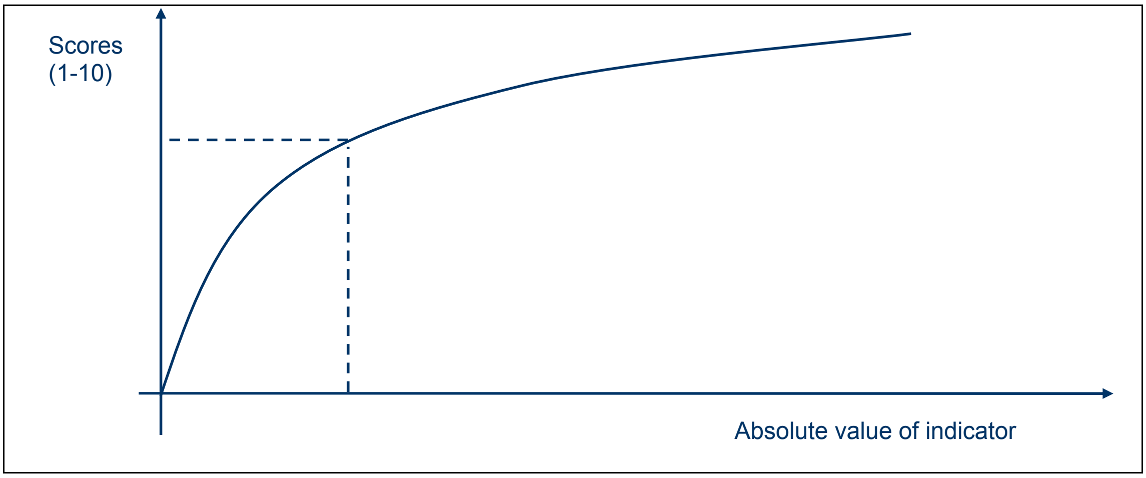

Figure 25: Example representation of indicator utility function

In some cases the utility function reaches a saturation point, where increasing absolute values do not contribute to increasing scores, or even might result in their decline. In other cases the utility converges at a score. So called K.O. criteria might also occur, which specify limits to growth or decrease of indicators. It predefines real values at which the related score reaches their limits, and it is not calculated from the utility function. It represents therefore a discrete relationship, where score can directly be given range of possible absolute values.

The introduced tools could be applied successfully for decision making at a given time period within a simple linear system, if all the indicators can be measured or calculated. However, real systems are dynamic and complex, including feedbacks and loops, reactions and interactions. Limitations of these tools for applying to complex and dynamic decision support in the future are therefore summarized as follows:

1. Objectives cannot be mapped at any point in time, since the system uses one single data-set. In this case, for the evaluation of each desired time period, data must be gathered, collected and processed. In most cases it is hard to have data for the same set of variables for each year.
2. It is not possible to apply them for future time without using additional tools, since identified indicators are rarely available for future periods.
3. The representation of a region with its feedbacks and interconnections cannot be implemented into the objective tree, therefore it must be represented with other methods.

To overcome these forthcomings and vulnerabilities, further possible methods and tools for making decisions must be investigated with capacities of involving complexity, feedbacks and dynamic features. Therefore, theory and possible application of existing decision support systems are reviewed hereon.

2.3.2. Decision support systems

Due to the large number of considerations involved in decision-making, decision support systems (DSS) have been developed to assist decision makers in considering the implications of various courses of thinking. DSS can support each of the before introduced decision making themes for better and more reliable results [Kirkwood,1988]. The concept DSS is extremely broad and its definitions vary depending upon the author's point of view, the specific subject or objectives [Turban,1993;Turban.E.,1993], [EC,1999a]. A DSS can take many different forms and the term can be used in many different ways.

DSS can be categorized as a class of knowledge based systems[7] or computerized information systems that support decision making activities. Any telecommunications- and/or computer-related equipment or interconnected system or subsystems of equipment that is used in the acquisition, storage, manipulation, management, movement, control, display, switch, interchange, transmission, or reception of data, and which includes software, firmware, and hardware, is called information system. Information systems include for example the computer software, among others. System dynamics modeling is an example of computer software, which studies and manages complex feedback systems [Forrester,1989]. Advantages of DSS can be summarized as follows:

- It is an effective and flexible tool to analyze dynamics of complex systems.
- It makes possible to trace behaviors of the system under certain conditions.
- Future threats and opportunities can be assessed with it.
- It allows checking coherence of assumptions of causality and definitions of variables.
- It enables the involvement of stakeholders, team work and creative cooperation and communication with others.
- Policy alternatives can be evaluated.
- Due to its “white-box” nature, it gives a better understanding about the analyzed problem and situation.
- It has a generic implications surface [Tesch,2003].

Considering these advantages, system dynamics has been selected to apply for current study. Chapter 6. introduces its concept and applications.

2.3.3. Sensitivity analysis

When developing and implementing a new alternative (investigation, project, etc.), a number of external and internal factors are likely to affect it. The *uncertainty* caused by future variability of those factors might occur at any level of decision making process [Hämäläinen,2002], which should be determined quantitatively. Uncertainties can be classified in many ways; one can distinguish knowledge uncertainty (uncertainties about information and data), quantity uncertainty (occurs in the level of empirical quantities, defined constants, decision variables or value parameters) and model uncertainty (including the before mentioned ones, beside the uncertainties of the assumption theories, the correlations of input components, etc.) [Yoe,1996]. If an uncertainty also includes exposure, it is called *risk*. According to Frank Knight’s definition, the risk is an uncertainty based on a well grounded, quantitative probability (measurable uncertainty) [Knight,1921]. Formally, risk was defined as follows:

Risk = (the probability that some event will occur) x (the consequences if it does occur)

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[7] Knowledge based system is a computer program that contains some of the subject-specific knowledge of human experts.

In stochastic, risk is an uncertainty for which probability can be calculated. Risk analysis is a systematic use of available information to determine how often specified events may occur and the magnitude of their consequences.

Sensitivity analysis (SA) is the study of how the uncertainty in the output of a model (numerical or other) can be apportioned to different sources of uncertainty in the model input [Saltelli,2004]. The aim of a SA is to explore how changes in the model influence the decision recommendation. SA besides aims to ascertain how the model depends upon the information fed into it, its structure and the framing assumptions made to build it. This information can be invaluable, as

- different level of acceptance (by the decision-makers and stakeholders) may be attached to different types of uncertainty, and
- different uncertainties impact differently on the reliability, the robustness and the efficiency of the model.

The nature of the uncertainty of parameter values is described by probability distributions, giving both range of values variables could take (minimum or maximum) and the likelihood of occurrence of each value within this range. Examples for common probability distribution functions are the nonparametric triangular distribution (defined by a minimum, most likely and maximum value) or normal distribution (defined by the mean and standard deviation), among others. Methods for SA can be classified as follows [Frey,2006]:

1. Mathematical methods, which typically involve calculating the output for a few values of an input that represent the possible range of the input.
2. Statistical methods, containing running simulations in which inputs are assigned probability distributions and assessing the effect of variance in inputs on the output distribution). Most common techniques are the Monte Carlo simulation, Latin hypercube sampling, and other ones.
3. Graphical methods give representation of sensitivity in the form of graphs, charts, or surfaces.

There are methods for assimilating the uncertainties according to the patterns of all individually estimated distributions of numerous variables, with other words for sensitivity of uncertainties. Among these, the Monte Carlo simulation involves for this objective the random sampling of each probability within numerous iterations of the model.

2.4. Introduction to system dynamics modeling

After introducing sustainable development (main concept applied) and describing the energy sector (subject analyzed within this work), the theory of decision making was viewed for making future sustainable decisions within the energy sector. Afterwards applied decision making methods were introduced, among them the LFA and DSS and their possible combination. In this section system dynamics modeling is introduced as a powerful and innovation tool for dynamic decision making.

System dynamics is a methodology for studying and managing complex feedback systems [Forrester,1989]. Feedback refers to the situation of ‘x’ affecting ‘y’ and ‘y’ in turn affecting ‘x’, perhaps through a chain of causes and effects. One cannot study the link between ‘x’ and ‘y’ and, independently: the link between ‘y’ and ‘x’ and predict how the system will behave [Forrester,1991], only the study of the whole system as a feedback system can and will lead to correct conclusions and results [SDS,2006]. The field is developed initially from the work of Jay W. Forrester, his book ‘Industrial Dynamics’ [Forrester,1961] is still a significant statement of philosophy and methodology. The central concept of system dynamics is the understanding of how all the objects in a system interact with one another. An example is presented in Figure 26, which is the schematic representation of the COSMOPAD dynamic model [Tesch,2003], incorporating economic, social and land use interactions with biomass systems.

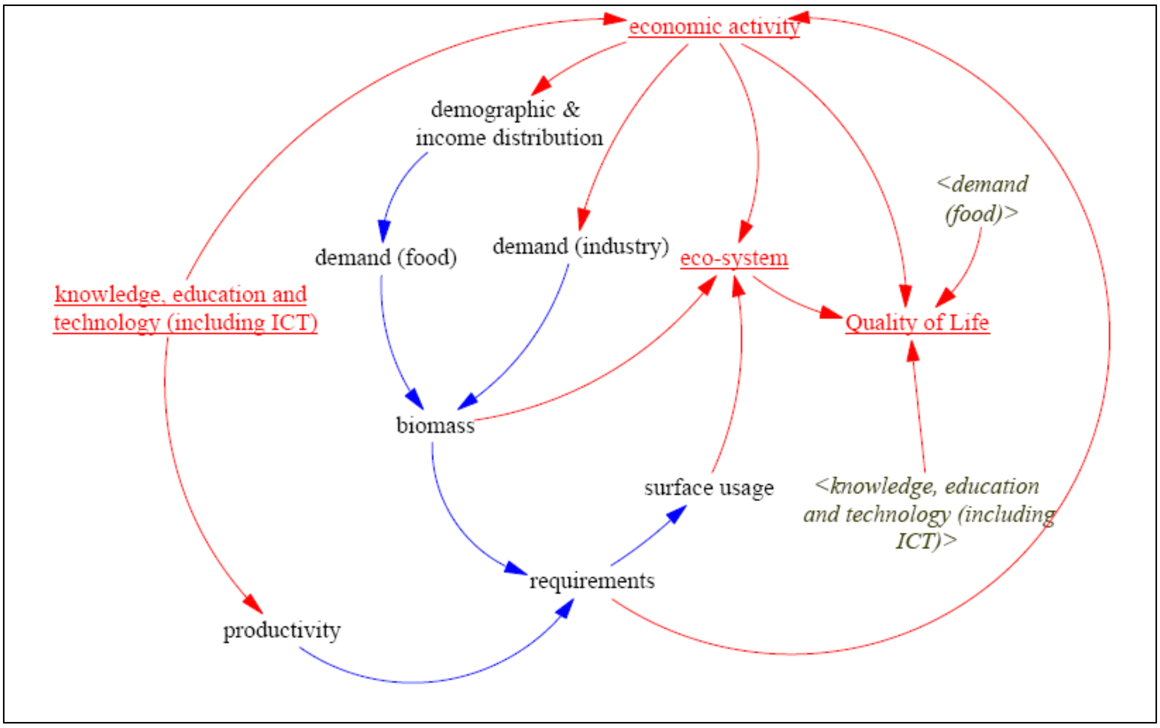


Figure 26: Example of interacting system components (Source: [Tesch,2003])

System dynamics combines the theory, methods, and philosophy needed to analyze the behavior of systems in the management, environmental change, politics, economic behavior, medicine, engineering, and other fields. System dynamics takes advantage of the fact that a computer model can be of much greater complexity and carry out more simultaneous calculations than what the mental model of the human mind can. System dynamic models therefore can be characterized as structural, disequilibrium, behavioral models; they are formulated in terms of the relationships between stocks, flows, queues, decision rules and influences. Stocks characterize the states of a system, its level or accommodation, while flows represent the rates of change of stocks [Kirkwood,1988]. In system dynamic models, the decision processes of agents are addressed by including the way people response to certain circumstances which emerge from the assumptions about the system's structure and interaction of feedback loops. Feedback loops exist when the outcome of a variable is directly or indirectly corrected by or related to the variable itself [Battjes,1999].

The process of system dynamics applies some of the principles of LFA: it starts with a problem identification to be solved - a situation that needs to be better understood, or an undesirable behavior that is to be corrected or avoided. Afterwards a dynamic hypothesis explaining the cause of the problem has to be developed, and built into a computer simulation model. The mental data base is a rich source of information about the parts of a system, about the information available at different points in time, and about the policies being followed in decision making, which will support the basic structure of the system and their behaviors. The model is afterwards tested to be certain that it reproduces the behavior seen in the real world. Alternative policies that alleviate the problem can be implemented and tested in the model [Forrester,1991]. A simplified flowchart of building and applying system dynamics model with policy implementation is showed in Figure 27.

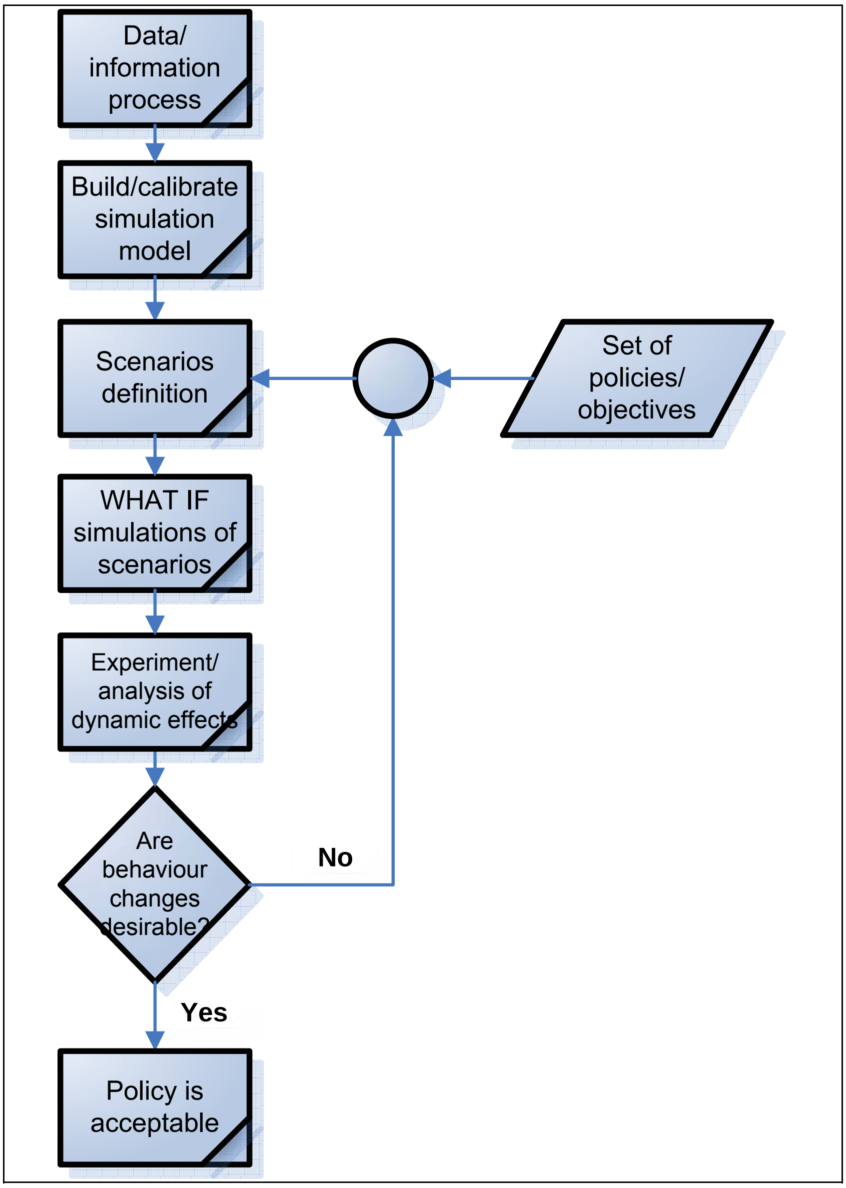


Figure 27: Policy implementation into system dynamics models

System dynamics is most useful for understanding how policies should/could/have affected demeanor. Emphasis should be made on designing policies that will yield systems with more favorable behavior:

1. one builds a simulation model from policies that in turn make decisions,
2. the model generates streams of decisions controlled by policies built into the model
3. the policies make all the decisions step-by-step in time as the simulation unfolds
4. then, if the resulting behavior is undesirable, one searches for a better set of policies [Forrester,1998].

In relation to the communication of objectives and results to the stakeholders, the members of the working group need to have a certain level of expertise. However, in order to accept such tools as decision support systems for scientific methods at administrative level they need to meet certain criteria:

1. they need to consist of an amount of components of a decision support system that can be understood by any user related to the subject in study,
2. the model structure and the mechanisms of prediction must be transparent and easy to understand,
3. the model must be capable of delivering credible, realistic results in calibration runs and
4. the decision support system must deal with relevant problems in the region and must offer a simple, common-sense view, clearly highlight the key components.

System dynamics fits to all of these features, and besides dynamic modeling can be used successfully for energy stocks and flows simulation, for application of the energy accounting approach and simulation of the interaction between economy, social and environmental systems, [Battjes,1999]. Therefore SDM was selecting as principle approach of this work, to follow decisions on BtE alternatives at a regional scale. Some of the software which allow decision support in a broad range of field of science are: Vensim DSS [Ventana Systems Inc.,2006], Extend [Odum,1996], MOHO - Multi Objective Heating Optimization, among others. Vensim allows providing a simple and flexible platform of building simulation models from causal loop or stock and flow diagrams and delays; therefore it was selected for this work. The software, in its general formulation, is a dynamic linear programming model with a mixed integer option. This implies that all relations that define the structure of a model are given as linear constraints between continuous variables [Ventana Systems Inc.,2006].

From a mathematical point of view, system-dynamic models consist of sets of differential or difference equations providing complex mathematical description of the system main processes [Ventana Systems Inc.,2006]. It focuses on behavioral aspects of the system in order to present a holistic rather than a reductionist view. So by using a model, it is coped with the complexity of the system by focusing on the significant causal influences. Models in Vensim are constructed graphically or in a text editor. Features include dynamic functions, subscripting (arrays), Monte Carlo sensitivity analysis, optimization, data handling, application interfaces, among others [Ventana Systems Inc.,2006]. Annex IV contains more description about Vensim and its features, toolbars and functions.

The general modeling process in Vensim starts with sketching a model and defining the components and their relationships with equations, than specifying their numerical quantities. Afterwards, the model is simulated and the resulting data can be examined with analysis tools (graphs, tables, descriptions) to determine the dynamic behavior of the components (variables) in the model and the differences between various simulations. The built, calibration and simulation of Borsod's system dynamics model within Vensim is given in Chapter 6 where the most important features of modeling are also given.

3. Scope of methods applied

The current work, as described before, aims at developing a methodology to simulate and analyze regional effects resulting from sustainable biomass use for energetic purpose. For that reason, first the energy sector in general was introduced, and their situation and application with special focus on RES and biomass in the EU and in Hungary, as well as the history and principles of the sustainable development concept. And since the goal is to support decision making in this field, principle concept and possible tools of decision making, were introduced and characterized.

This chapter introduces and describes an innovative step-by-step approach for such reason, including existing and developed concepts, methods and tools. The developed tool-set is aiming to serve as a flexible and applicable model, containing several activities in various levels, which can be useful for decision support. A general summary and an overall view of the developed tool-set is given, as presented in Figure 28.

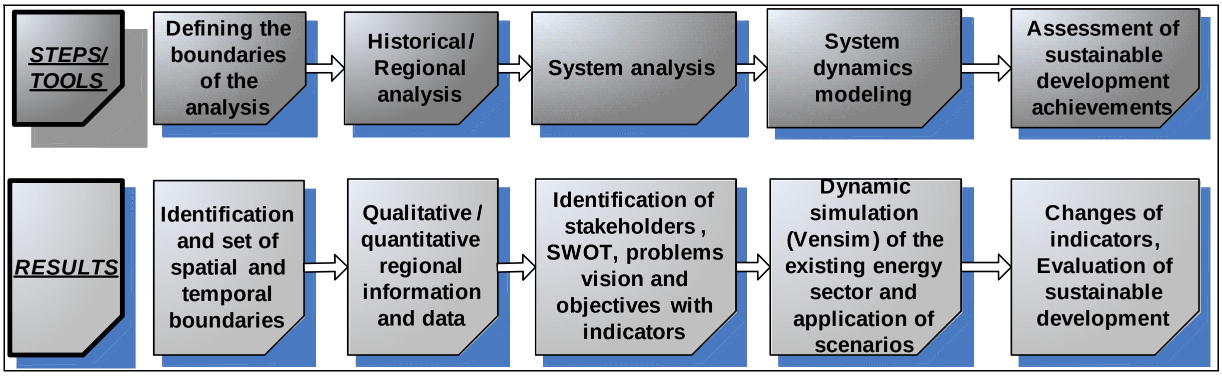


Figure 28 Short methodological overview of the developed tool-set

As first step, physical and temporal **boundaries** of the system in focus must be set, to draw limits around the study. It is given by defining *spatial boundaries*, wherein the analysis is to be performed. For that reason related literature has been reviewed and existing spatial classification applied and combined. On the other hand *temporal frames* were set, i.e. the beginning and end of the simulation period. Features and limitations of the modeling, as well as availability of regional data have been analyzed for establishing temporal boundaries.

After boundaries are set, the selected region must be analyzed to gather and process local information, know-how and data needed. For that reason several regional description, statistical and other databases have been collected and analyzed for having soft and hard data. Afterwards the **analysis of the whole system** is processed by applying the principle components of LFA and its extensions, incorporating stakeholder analysis, structuring the identified problems and regional objectives. The *objective system* built represents the overall goal of sustainable development, as well as the bottom level objectives identified through the complex regional analysis. At the bottom-most level take place the *indicators*. Weighting method AHP is applied to quantitatively distinguish among relative importance of objectives and indicators. Real values of indicators are transferred into scores via utility functions, which, through implementing them into the objective tree, allow quantifying the achievement of sustainable development. To perceive future (indicator) values and to represent the region as a complex dynamic and feedback entity **system dynamics model** has been built and calibrated. Afterwards realistic scenarios have been formulated within the biomass sector and simulated in the model to follow quantitative changes of selected components or indicators. Finally, future indicators resulting from the simulation are implemented back into the objective system, so the objectives and principle goal of sustainable development can be quantitatively analyzed and compared. Figure 29 represents the main steps with detailed sub-tasks, which's progress is than introduced within this chapter in details.

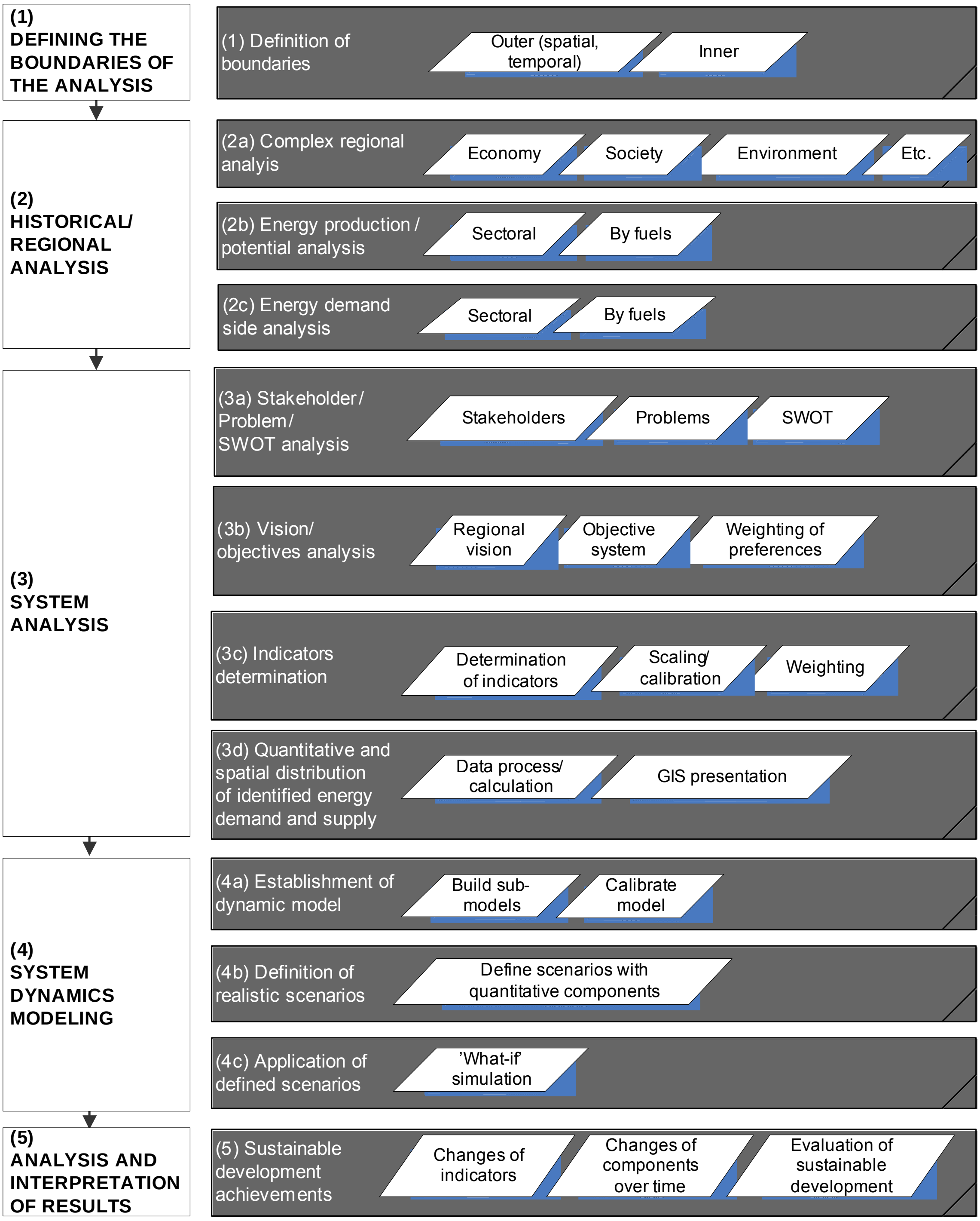


Figure 29: Structure of the developed regional decision support tool-set in the biomass field

4. Regional analysis of Borsod County

As described in Chapter 3, the here developed tool-set starts with setting the boundaries of the system under study. Afterwards the complex analysis of the region in focus (Borsod) was performed in order to acquire information about its history, current economic, social and environmental position for identifying the burdens of its sustainable development and set future objectives. , a complex analysis of the region is needed. This is carried out within this Chapter, starting with setting the borders,

4.1. Defining the boundaries of the study

When analyzing a complex networked system, such as a region, it is not possible to take into account all the possible actions, reactions and feedbacks between all the components and between the system and its environment. Therefore the sphere of research must be constrained, and thus boundaries must be defined to distinguish net inputs from internal transactions. Net inputs are independent and exogenous whereas interaction are interrelated and endogenous [Battjes,1999]. Through drawing outer boundaries, it can clearly be understood and described where the system examined starts and ends spatially and temporally [Schmitdt,2004]. In addition to this outer boundary there is an inner boundary, namely the level of detail represented by the sub-systems [Mansfield,2006]. For analyzing complex regional effects resulting from various utilization forms of biomass, this chapter begins with the set of both outer (spatial, temporal) and inner (system) boundaries.

4.1.1. Spatial boundaries

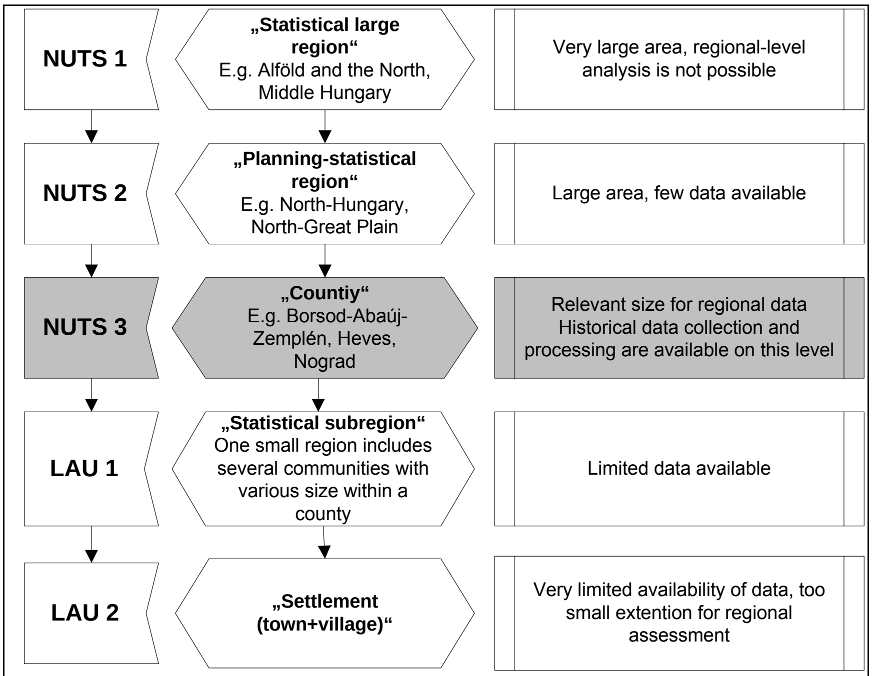
Biomass is a local source, therefore its potential, burdens and possible uses can be evaluated successfully in a regional or local scale, considering all needed political, geographical, social, economic, environmental and technological conditions. For the performance of this study, an appropriate spatial level has been selected, taking into consideration the following aspects:

- Existence of administrative borders
- Size of the area: large enough for analysis, but rationally possible small size in order to represent all important components
- Share of biomass sources: possible high share of agricultural and forest land and/or amount of biomass production
- Data availability: accurate amount and quality of periodical data must be available for the investigations
- Existing know-how and contacts established have to be taken into consideration.

Firstly, the European and Hungarian spatial distribution systems have been analyzed to select possible existing geographical and administrative units of analysis. The Nomenclature of Territorial Units for Statistics (NUTS) was established by Eurostat [EC,1988], in order to provide a single uniform breakdown of territorial units for the production of regional statistics for the European Union (EU). Goal of the establishment of the NUTS is to manage the inevitable process of change in the administrative structures of Member States in the smoothest possible way, so as to minimize the impact of such changes on the availability and comparability of regional statistics [MKK,2001]. From 2004, the regions in the 10 new Member States, including Hungary, have also been added to the NUTS. NUTS 1 in Hungary includes the statistical big regions, and NUTS 2 represents the planning statistical regions. Both levels appear very much extended where it is hard to perform regional analysis. In addition, since NUTS 2 categorization exists only since 2004, only few amounts of data and information are available on this level.

In Hungary, the upper Local Administrative Unit (LAU1) level identifies the subregions, whilst the LAU2 level represents all the communities. Both could be relevant for regional analysis in respect to the size, but data available are collected from community level, which are nonetheless very limited and varies by sources and proceeding methods.

Therefore NUTS 3 level has been considered as having relevant extension and appropriate level of data available (even though from different sources). Among counties the Eastern regions have been considered, where still few investments are realized, but there is available biomass, manpower and interests from the EU as well as from Hungarian aspects. Due to the extended forest and agricultural areas and the previously established contacts and gathered information Borsod-Abaúj-Zemplén County (Borsod or BAZ) was selected. The positioning of Borsod within the Hungarian spatial system is illustrated in Figure 30 whilst further boundaries of the study are described in the next section.



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NUTS: Nomenclature of Territorial Units for Statistics
LAU: Local Administrative Units

Figure 30: Positioning of Borsod County within the NUTS spatial system in Hungary

4.1.2. Temporal boundaries

The temporal accessibility of reliable information, the modeling capabilities and reasonability, as well as future demand of desired information represent a temporal boundary for the study, which can be divided into two parts:

- Pre-temporal frame: historical time period from which data have to be collected, depending on the requirements for calculations of model variables as well as on the reliability of data accessible. Central statistical data in Hungary are available at a yearly frequency since 1990, also at county level. On the other hand, for the modeling it is necessary to have data of about a 10-15 years historical period, considering that regional features can be analyzed within this period, which are also essential for model calibration. Therefore for current analysis most of yearly data have been collected from 1990. However, in some cases older historical data have also been analyzed, whilst in calculation of certain components was sufficient a shorter time period, in order to have a more realistic picture.
- Post-temporal frame: according to the modeling capabilities and input data, a certain future period can be analyzed with high soundness, which is usually not longer that the pre-temporal frame. Considering moreover that important EU and national goals in the RES field are set until 2020, results of the analysis have been performed until 2020. However, these long term results have to be seen with a higher insecurity, since the economic, social and political circumstances can vary, sometimes suddenly or unexpected within such large period.

Due to the continuously changing legislations, prices, conditions of energy production and consumption, among others, the work considers the 2004-2006 as ‘current year’ (in few cases more recent sources have been implemented as well).

4.1.3. System boundaries

The utilization of biomass for energetic purpose is an expansive and complex subject, including several different sources, conversion and transport methods, technologies, energy types and their uses. To avoid a much extended analysis, these system components have been limited. First, among biomass sources the agriculture and forestry sectors have been investigated within this study as sources, whilst communal and agro-industrial sectors are considered only as consumers. For more detailed set of other components, such as technologies, conversion and use, the following aspects must be taken into consideration:

- Besides the overall goal of sustainable development, the subjects analyzed have to suit to the region’s history and vision, goal and identified objectives
- Realistic solutions must be in accordance with the regional specifications and potential
- Available know-how and technologies must be taken into consideration
- Components can be evaluated if there is available information and data

As it can be seen, to set the detailed system boundaries, to identify what components with which details should and could be included, first the county of Borsod must be analyzed, with special focus on the energy sector. Borsod County has been performed with appropriate data management, presented in next sections.

4.2. Data management

Once the goal and boundaries of the study are set, information must be identified, collected and processed into data needed, since every process improvement effort relies on data, providing a factual basis for making decisions [BSC,2003]. This is also a crucial step, since the quality, quantity, type and soundness of data will influence the applicability and reliability of the results obtained. Data management comprises all the disciplines related to managing data as a valuable resource. Collection implies the identification of data needed, searching for them and collecting into an appropriate database. Data processing or data conversion can be applied to any process that converts data from one format to another, or information into data. Major **aspects** when collecting and processing information and data are the following [Taylor,1996]:

- Accessibility: where and how can data be gathered
- Data coordination: sharing and management of data
- Cost: purchase of data
- Usefulness and appropriateness of data
- Intellectual property and ownership restrictions
- Type of data: e.g. qualitative vs quantitative
- Process: how data can be collected

Considering the described aspects, the following **process** of data collection and conversion has been established within this work [DoE,2002], [Taylor,1996] (Figure 31):

1. Pre-data management steps
    1.1. It is important to clearly define the goal of the study, objectives and requirements in order to ensure the proper data is gathered. Through coordinating the data collection requirements with the overall objectives of the study information can be collected in a more time and effort efficient way. Therefore information have been gathered about Borsod’s economic, social, environmental and political past and present situation, as well as detailed and specific data in the fields of energy production, conversion and consumption processes.

1.2. Establishment of operational definitions and methodology for the data collection are required with the following components: how many observations are needed, what time interval should be part of the study and at what spatial level. These constraints have been identified and described previously, as spatial and temporal boundaries. According to that, data are needed from Borsod County, from the past 10-15 years, with one year time interval. Besides, forecasts and estimations of several variables are required and useful until 2020 for future model calibration.

1.3. Possible methodologies and processes must be identified to record all data: calculation, estimation, forecast etc.. Possible methods are introduced within Chapter 3, whilst the applied ones of those are described by the representative steps.

1.4. Data collection (and measurement) repeatability, reproducibility, accuracy, and stability should than be ensured, which is provided with flexible data base and documentations.

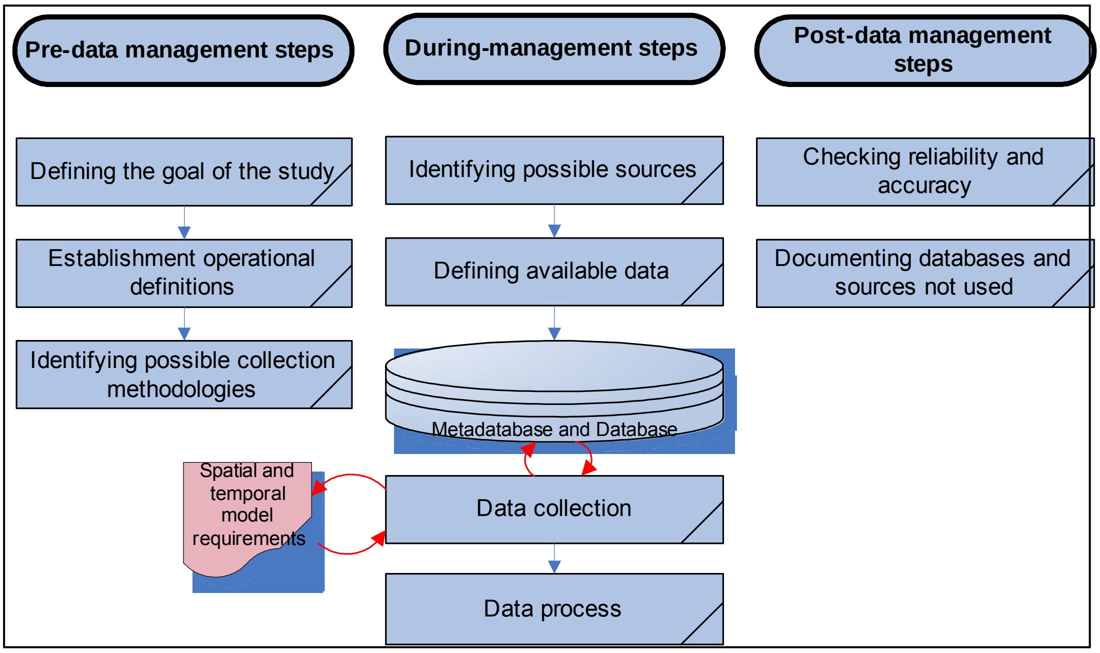


Figure 31: Process flowchart of data management applied

2. During management steps

First available and key **sources** of information must be identified that address the research demand. It was performed in various levels.

Available relevant information should be **collected** as early as possible in the study to gain an understanding about the whole availability and lack of information required.

The next step is to **process** data into the desired unit of measurement. A principal rule was followed by this activity, which is to keep raw data with composed notes about their origin to make it easier to identify in the future. In each case data have been displayed by graphs and analyzed to prove their adequacy and reliability. For that purpose data from different sources have been compared with their processing methodologies and sources as well. Since modeling has its specific data requirement, raw data have been converted into that form through various methods, combining hard and soft information.

The data collection process is supported by the establishment of a systematic meta-database as well, including meta-information of data, such as name, type and unit and source of data, which are presented in Annex V. Copies of original and processed information have been entered into a database, which's continuous updating and proving ensure their practicability and actuality [Patrick,2004]. Since this process is different for most of the data, their descriptions can be found at the related parts of this study. It must be emphasized again, that the process of data collecting and processing is iterative, depending on their availability on one hand and the modeling demand on the other hand. Future data are gathered from forecasts and estimations, or processed by the system dynamics model built, detailed in Chapter 4.2.

3. Post-data management steps
   Referring back to the question of whether or not the data collection and measurement systems are reproducible, repeatable, accurate, and stable, results must be reliable. Several **methods** can be applied for data collection, the most commonly ones are the following:
   3.1. Survey: collecting standardized information through structured questionnaires to generate quantitative data.
   3.2. Case study: in-depth examination of a particular case.
   3.3. Interviews: information collected by talking with and listening to people.
   3.4. Observation: collecting information through 'seeing' and 'listening'.
   3.5. Group assessment: use of group processes to collect evaluation information such as nominal group technique, focus group, Delphi, brainstorming or community forums.
   3.6. Expert or peer review: examination by a review committee, panel of experts or peers.
   3.7. Testimonial: individual statements by people indicating personal responses and reactions.
   3.8. Tests: use of established standards to assess knowledge, skill, performance.
   3.9. Photograph, slide, video: use of photography to capture visual images.
   3.10. Logs: recording of chronological entries which are usually brief and factual.
   3.11. Document analysis: use of content analysis and other techniques to analyze and summarize printed material and existing information [Taylor,2002].

For current study surveys, case studies, assessments, maps, photographs, statistics, document analysis and interviews have been applied. Results are databases with data names, units, time series and sources, as well as data-bases. These can significantly contribute to future investigations focused on analysis based on renewables or research or investigations planned in Borsod. Furthermore the description of data sources gives information about the European, Hungarian and regional participants in the energy sector and its state.

4.3. Spatial distribution of Borsod

Using the collected and processed information, relevant figures and descriptions about County BAZ have been prepared, from which first the county's positioning is presented hereafter. Borsod County is located in central Europe, in northeastern Hungary, on the border with Slovakia. As shown in Figure 32, it share also borders with the Hungarian counties Nógrád, Heves, Hajdú-Bihar and Szabolcs-Szatmár-Bereg. The capital of Borsod is Miskolc.

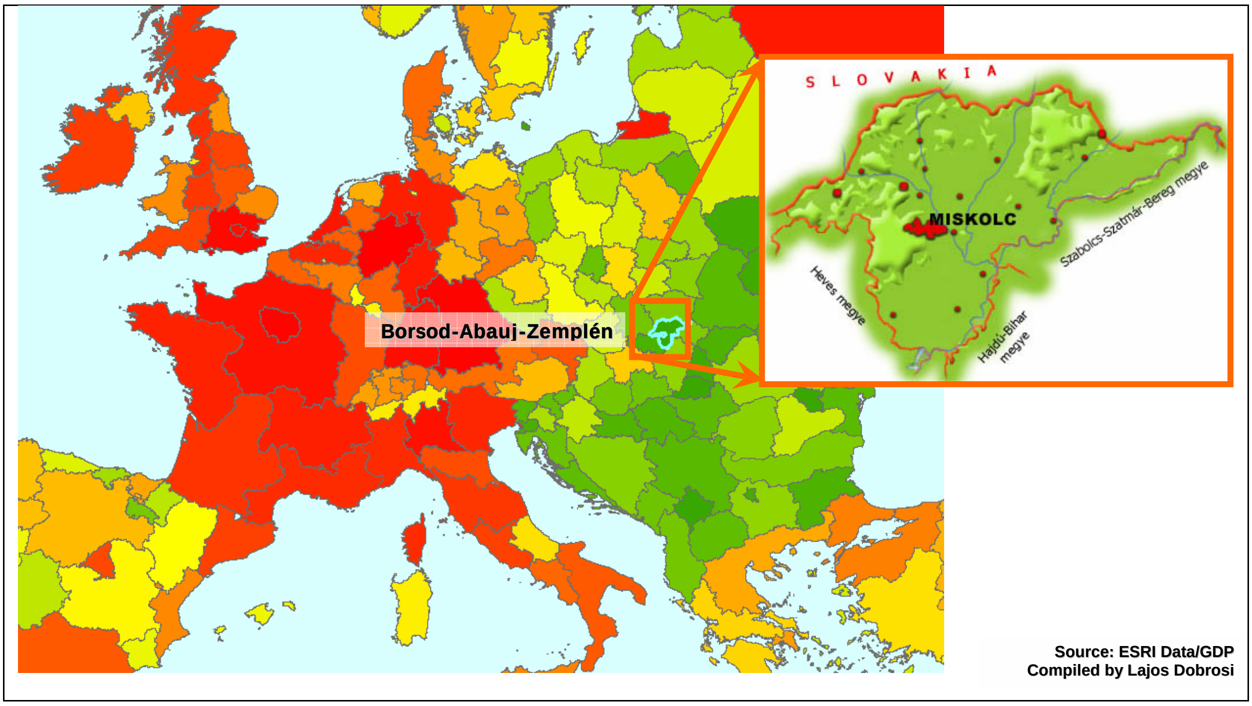


Figure 32: Geographical position of Borsod County within Europe

Distribution of land use and land cover is important when analyzing an area's spatial features. Land use refers to how the land is economically used by humans (e.g. for industrial or commercial purpose). Land use represents in this manner a territory characterized according to its current and future functional dimension or socioeconomic purpose [EC,2004b]. Land cover, on the other hand refers to the physical and biological cover of the earth's surface [EC,2004b], representing the vegetation, structures, or other features that cover the land (forest, grass, water, etc.). Land cover, land use and their changes are identified as important indicators by the OECD [OECD,1993]. The integration of their environmental concerns into energy policies are implemented in the 'Indicators of sustainable development' [UN,2001] [UN,2007]. Applying land cover/use analyses facilitate to measure sustainable spatial development. As examples the following applications can be named: assessing the degree of fragmentation of natural areas; tackling climate change (by mapping spatial glacier retreat); assessing the effectiveness of agricultural policy and loss of biodiversity; mapping the impact of environmental disasters; monitoring urban development (enlargement of settlements and commercial areas), among others [EEA,2000]. Within this study the historical and current spatial information have been gathered, and future changes are modeled in the Chapter 6. As input for this analysis, the database of the European Topic Centre on Terrestrial Environment (ETCOTE) has been used, as well as the 'Territorial settlement plan' of Borsod [Koszorú,2002], county development plans [NORDA,2006] and statistical data [KSH,2004b]. The processed Corine maps [EEA,2000], [EC,2006d] give unified land cover classifications for European countries, among them for Hungary as well, with five main distribution. The 'Territorial settlement plan', according to the 60/2002 (IX.26) resolution, includes Borsod's structural and regional regulation plan [Koszorú,2002] which divide the county into six geographical categories, furthermore two main zones are identified, namely protection and functional zones. Both, the Corine land cover and the classes of the 'Territorial settlement plan' are presented in

Table 6 and in Annex VI. Google maps from the Google Earth software also have been used to gather further spatial information. Other needed information have been collected from local statistics [KSH,2004b], regional assessments [Gelsei,2006], and development plans [NORDA,2006]. Those, the various data and input have been processed into numerical and spatial geographical information through mathematical calculations, digitalization and using further functions of the ArcView GIS software [ESRI,2001] as briefly presented in Figure 33, whilst land cover map is shown in Figure 34.

Table 6: Comparison of spatial classifications

Classification of Corine	Classification given by the Territorial settlement plan
Artificial surfaces	Characteristically agricultural area
Agricultural areas	Characteristically forest area
Forest and semi natural areas	Area with characteristically mixed use
Wetlands	Characteristically settlement area
Water bodies	Surface waters
Other	Uniquely defined areas

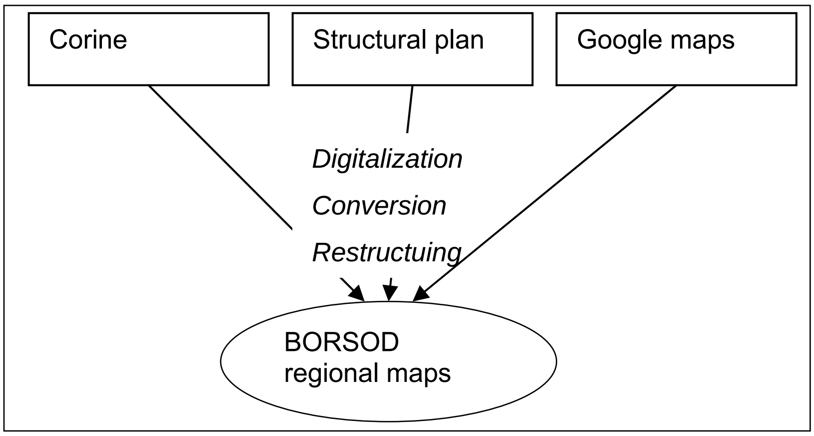


Figure 33: Spatial data process of Borsod

As it can be seen in Figure 34, most of the plain areas of Borsod are cultivated as arable land or meadow. Adding also the statistical information from 2004, 60 % of Borsod is covered by use of arable land, basically in the center of the county. Forest areas can be found at the western and northeastern fields, representing 24% of Borsod. Besides, the repository of the natural resources is enriched with forests, caves and thermal waters; 13% of the county are natural protected areas [Gelsei,2006]; 16% is uncultivated area, mostly urban areas, locating in the vicinity of agricultural and forest fields.

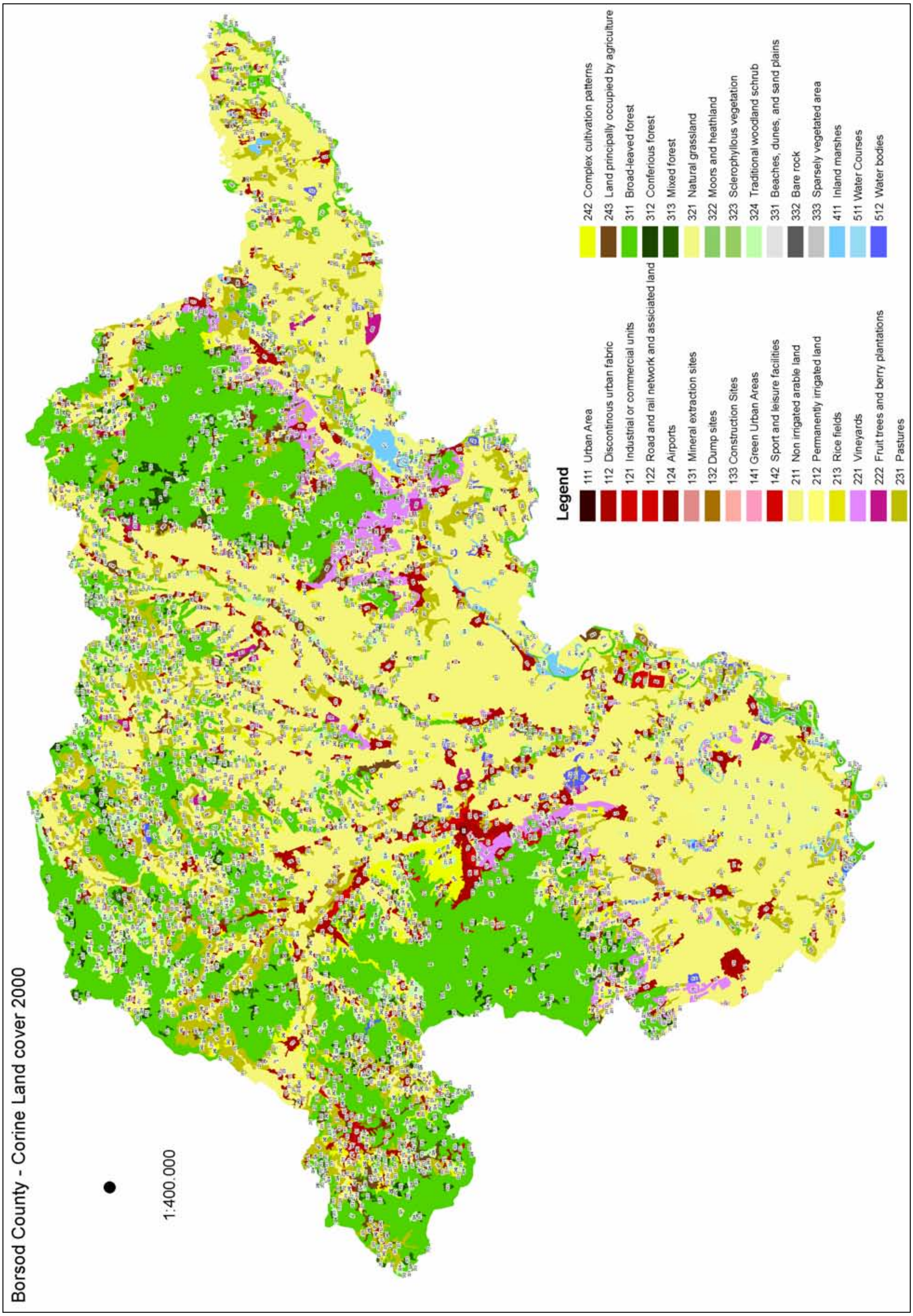


Figure 34: Land cover map of Borsod County

4.4. Demography and social situation

The historical and future changes of the population size and composition are crucial to know and estimate for regional decision making. Demographic situation is also important when analyzing energy production and consumption patterns, taken into account the following facts:

- size and changes of the population within a region is a social and economic component
- the population size has a high correspondence with the consumption of primary and final energy sources and it is a crucial factor when estimating the future consumption of energy
- increasing population might affect the land use distribution of a region, if available lands have to be converted into built up ones
- growing population produce an increasing amount of waste, the bio components of which can be considered as biomass potential for energy
- the more people, the higher consumption of agricultural products, which might increase the precedence of agricultural commodities against the energetic plants; however this consideration must be taken critical, since transportation of food from other regions in Hungary, as well as import represent supply
- the migration of people is influenced by given working and living conditions (which partially also originated from the energy sector), its workplace-capacity and its contribution to the air-quality changes

Therefore available information of the Hungarian Central Statistical Office (KSH) [KSH,2004b] have been collected, analyzed and processed from the last fifteen years. The population of Borsod adds up to a 7.2% share of the Hungarian total population, with approximately 732,000 inhabitants as of the year 2004 (see Figure 35). This number has continually been sinking over the last two and half decades, resulting from tendency emigration [Koszorú,2002]. The Secretariat of Commission on Population Policy of Hungary (NÈPINFO) includes detailed population forecast until 2021 [NÈPINFO,2006]. According to the studies of NÈPINFO, it is expected that Borsod's population will continue to sink, and that by 2021 only 93% of the 2001's inhabitants will be living in the county. In Borsod the dependent population is the highest in relation to the national level [KSH,2004b] and there is a high share with disadvantageous social situation. Despite the recent regional expansions, the obsolete production conditions detain the professional and technological development, which has been risen due to the changes in the industrial and agricultural sectors. Generally a pessimistic and outlook is revealing among the people, with low mobility and initiative skills. Even though it has been a progress towards technology and know-how development, still both have a low appreciation.

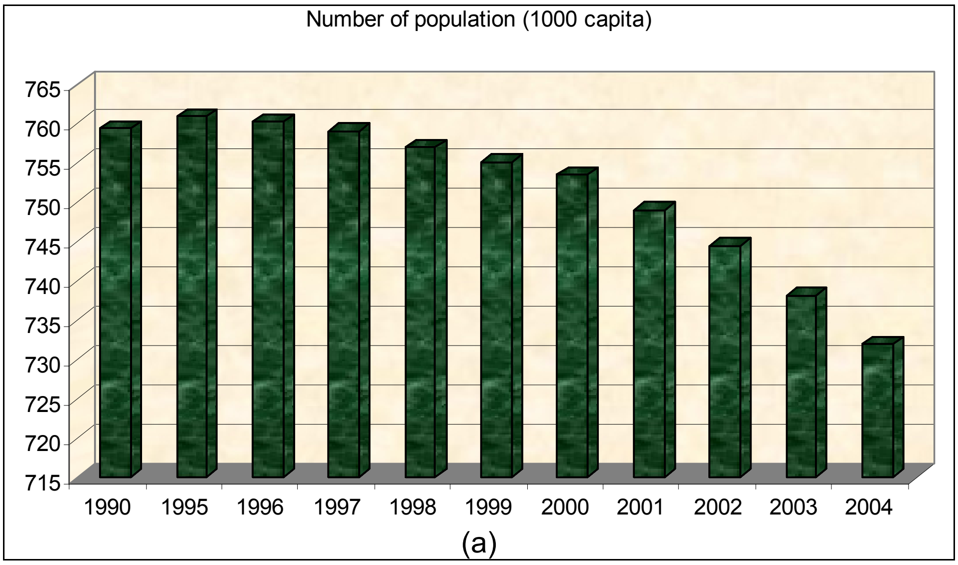


Figure 35: Population figures of Borsod County between 1990 and 2004

4.5. Diagnostic of the economic and industrial situation in Borsod

Economy is one of the main driving forces of any activity, and a fundamental pillar of the territorial competitiveness. Create and retain value added and strengthen the links between sectors are regional and national objectives to be fostered. Data sources to describe Borsod's economy are mostly statistical figures [KSH,2000], [Fehér,2006], [KSH,2005a], [KSH,2004b] and regional development concepts [ME,1999a], [NORDA,2005], [Gelsei,2006].

Due to the emphasis on industrialization during the former Socialist regime and the huge brown coal exploitation, Borsod became one of the leading industrial regions. With the fall of the Socialist regime the industry faced a crisis, and currently Borsod is among the counties that have the highest rate of unemployment and also the lowest rate of GDP per capita in Hungary (1,142,000 Ft/capita in year 2003). However, it should also be noticed, that a sort of revival of the regional economy has been taking place since 1996, and there have been some changes in R&D activities as well, although these figures still indicate a slow development of the county [Tóth,2005a]. The number of registered enterprises and average income in all sectors is also much lower than the Hungarian average.

Table 7 includes selected economic indicators of BAZ and Hungary for comparison in year 2004.

Table 7: Selected economic indicators of Borsod county (year 2004)

Indicator	Unit	Borsod county	Hungary
Unemployment rate	%	10.9	6.1
GDP/capita	Ft/capita	1,142,000	1,817,000
Registered enterprises	number/1000 person	76	119
Industrial production	Ft/capita	1,336,900	1,523,900
Monthly gross wage	Ft/month	123,019	145,059
Built houses	Piece/10.000 person	16.9	43.4
Investment per capita	Ft/person	327,370	298,265

Only eight percent of the foreign enterprises in Hungary are established in BAZ, a relatively low value that can be explained with its distance to the western border and its still vulnerable economy, as well as its high unemployment rate.

The county has been beyond the pale of the national and international investment centers and axes: only 11% of the national investment came into Borsod in year 2004, which is still a very low achievement, but can be considered as development when comparing to the 4-6% of last decades. The main economic production of the county is resulting from services (60% of value added (VA)) and industrial production (30%); construction and agriculture are contributing with 4% and 5%, presented in Figure 36. There are already some positive achievements in the biomass field, for example the establishment of the Innovation Cluster Center (IKC) in Gyöngyös, bringing investment and know-how to the region, or the retrofit of boilers from coal to biomass use.

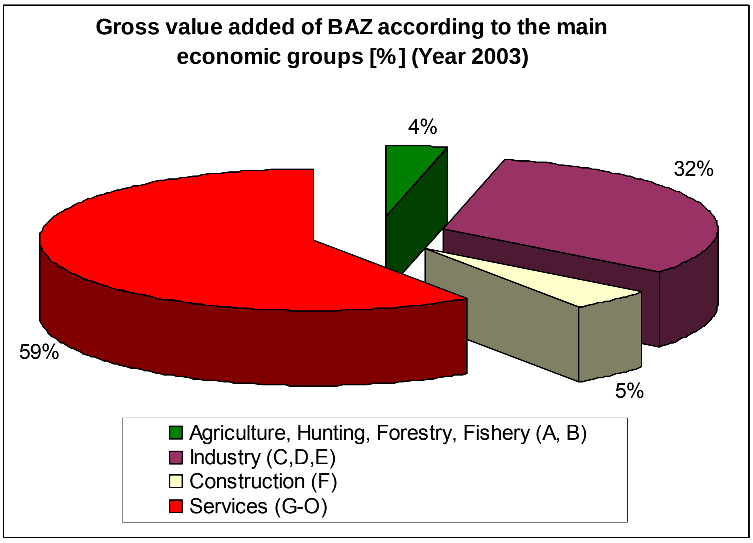


Figure 36: Sector distribution of gross value added of Borsod County (Year 2003)

There are huge differences among the sub-regions of BAZ in terms of their production: Miskolc sub-region gives 40% of the VA, Tiszaújvaros 27%, Kazincbarcika 17%, forming in this manner a geographical axis. The non-industrial small regions have a very low production in comparison and hence an underdeveloped economic situation [ME,1999a].

The industrial production has shown strong development during previous years, approaching the Hungarian average. Industrial data are given according to the Statistical Classification of Economic Activities in the European Community (NACE) distribution [EC,2007f]. Annex VII summarizes the NACE classification and the Hungarian one within the industry sector.

The most important sector of industrial production are the manufacturing, chemical industry and machinery, but minerals and food industry have also an important share, summarized in Figure 37. The industrial production per capita was 1,337,000 Ft in year 2004, when almost 50,000 people were employed in this sector. There are also several industrial parks in Borsod, the most significant ones are the Diósgyör, Tiszaújváros and Kazincbarcika.

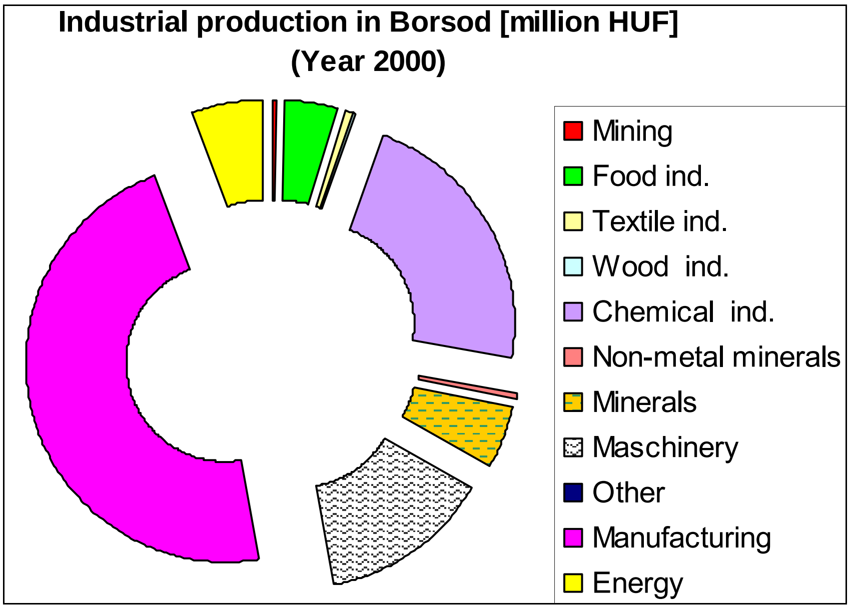


Figure 37: Share of industrial production in Borsod (year 2000)

4.6. Agriculture, forestry and their management

4.6.1. Agricultural production in Borsod

In general terms it can be stated that natural makings are unfavorable for traditional agricultural production in a huge part of the county [Kovács,2006], due to low quality areas, regional structure, the lowering rural population and the city-centric development policy. Less favored areas are defined according to 1257/1999/EK [EC,2007b], which is also included within the National Development Plan in Hungary [MKK,2003]. At the end of the 80's an adaptation crisis has begun in the agriculture, which nowadays is still coming to pass. The farmlands are characterized by a high number of uncompetitive small farms and huge farms with adaptation problems. A remarkable statement can be made by analyzing the land covers and their respective GDP values. Whilst almost 93% of the county is covered with various agricultural and forest areas, only 4% of the gross value added is coming from these sectors. This shows the unproductivity and low efficiency of the sector, but at the same time it points out their future potential, which could be exploited through more sustainable utilization patterns. Figure 38 gives an overview of the share of main agricultural areas in Borsod. Besides arable land (64%) grassland has a high share (30%), whilst garden, orchard and vineyard sup up 6%. Further distribution of the arable land is shown in Figure 39a. As can be seen, traditional production (wheat and maize) take place in a significant part of the field; besides barley and sunflower are produced with great amount. The rape plantations have been increased recently, especially for energetic purpose. Among animal production cattle has high importance, as represented in Figure 39b.

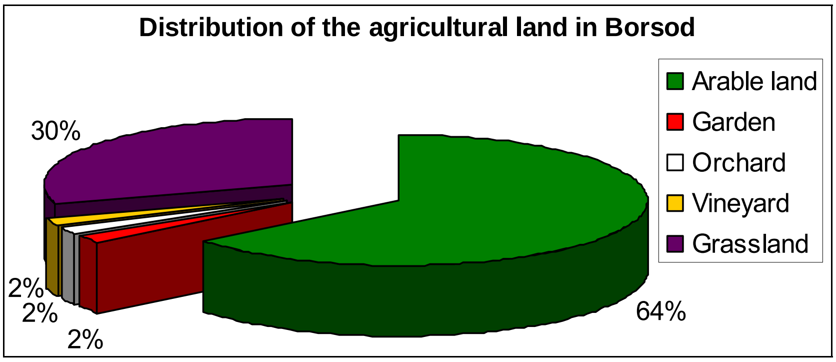


Figure 38: Distribution of the agricultural land in Borsod

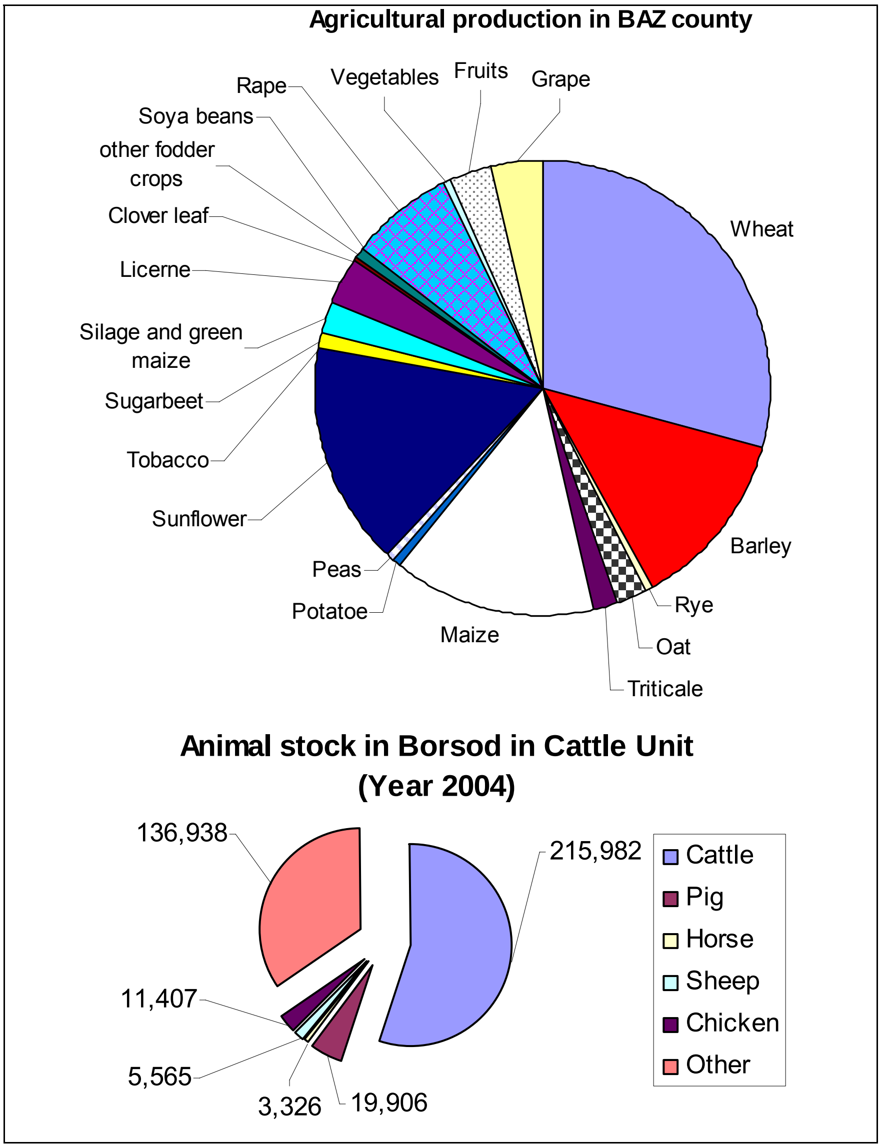


Figure 39: Agricultural crop and animal production in Borsod County (year 2004)

The traditional production of wheat and maize can not be considered as rentable; therefore, overproduction of those crops signifies one of the major problems in the agriculture [Fehér,2006], but the sector faces further problems as well: the transition of ownership, the region (and Hungary as well) lost a significant part of its traditional market, there is a lack of capital, the farm structure is broken up, the shortage of knowledge, experts, technology and investment, etc. [Bai,2002]. Even though there have been policy changes and development in the fields of agricultural and rural developments (farm-electrification, rural development plan, etc.), several further objectives can be set to reach a more competitive and sustainable agricultural production. Such objectives are for example the increase of diversification level, the diminishment of overproduction, the combination of agriculture with rural development, the establishment of new workplaces. Among achievements the experimentation of energetic plantations can be named, aiming at finding appropriate biomass sources for the increasing energy demand.

4.6.2. Forests and their management

A **forest** is defined as an ecosystem or assemblage of ecosystems dominated by trees and other woody vegetation. The living components of a forest include trees, shrubs, vines, grasses and other herbaceous (non-woody) plants, mosses, algae, fungi, insects, mammals, birds, reptiles, amphibians, and microorganisms living on the plants and animals and in the soil. These interact with one another and with the non-living part of the environment - including the soil, water, and minerals. Forest is different of agriculture because of the following ones:

- the production cycle is decades long, sometimes centuries
- woody biomass is primarily used for furniture industry
- the cut and harvest of forests is limited
- circulation of money is infrequently
- besides the production function there are social functions as well, such as protection or social welfare
- the ownership structure has high importance because of economic questions and management possibilities
- the change of any policy or management pattern has long time effect, with few direct feedback

Forest area in Hungary refers to an area covered by forests grater than 1,500 m^2 [HR,1996]. In recent decades, negative changes of the natural environment, such as the overall decline of forest areas, have led to increasing the value of natural resources. As a result, developed countries have redesigned their forestry policies, giving higher priority to protection, human-environmental and social functions. The wood production function, which dominated in the past, has become subordinate to environmental considerations. The activities of social movements have led to the inclusion of forest policy in the overall socio-political programs of governments. A similar process has occurred in the Hungarian forest policy following the ratification of international treaties by the government. Three basic principles underlie the goals of Hungarian **forest policy**:

- Sustainable forest management: this principle is in line with the principle of sustainable development declared at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992 [UN,1992]. It orders that the aspects of forest protection must be taken into consideration, as well as the right and undertaking of forest owners, and at the same time support the forestry management with several tools in order to be able to protect the concern of the society in a long term. Besides, the surface, production potential, as well as ecological and immaterial values of forest cannot abate.
- Near-to-nature forest management: this principle is closely related to sustainable forest management, which should be carried out wherever feasible, taking into consideration site and economic-investment factors. Sustainable and near-to-nature forest management fulfils international commitments such as preservation of the diversity of the natural environment, maintenance of forest gene reserves and adaptation to undesirable long-term climatic change.
- Plantation of new forests: increasing forest cover by new planting is an old Hungarian forestry policy principle, and aims to meet social and political goals. Major efforts in this direction reaped considerable results in the post-World War II period: forest cover increased from 12% to 20%. However, this level is barely half of the average forest cover level throughout Europe (33–34%) and considerably lower than the desirable minimum for Hungary (25%) [Rumpf,1998].

Forest management in Hungary is regulated by the Office of Forestry in the Hungarian Ministry of Agriculture and by ten State Forest Inspectorates; however, the Ministry of Environment has primary responsibility for protected forests. The first forest law is originated from Maria Theresa in 1770 (National Forest Order), afterwards the first forest operation plan ('üzemterv') has been issued at the end of 18^{th} century, whilst the first national forest corporation in the 19^{th} century. Since then several law regulating forest management have been made; current legislative regulation is the LIV/1997 law in force [HR,1996]. It fosters the growing of forest area and stock; for this purpose extracted wood material is not allowed to exceed the yearly increment. Forest plantations with the principal goal of generating biomass are not considered to be 'real' forests in the biological sense. Legislative background of energy forests in Hungary is already under progress.

Relevant sources of information and data in the field can be found in international sources, such as Eurostat [EC,2006b], OECD and IEA [IEA,2002b], among others. Besides, information about forest and forestry, as well as wood statistics are collected for exampfrom the Hungarian Central Statistical Office, State Forest Service or Energy Centre Hungary. As result it can be stated that the more than 175,000 ha of forest areas in BAZ contain 40 million m³ stocking, especially with species of oak, beech, hornbeam and robinia [ÀESZ,2002], [ÀESZ,2006]. The forest density of BAZ is relatively high in comparison to the Hungarian average, presented in Figure 40. 32% of the forest is protected with restricted use and production, and 30% is in private hands.

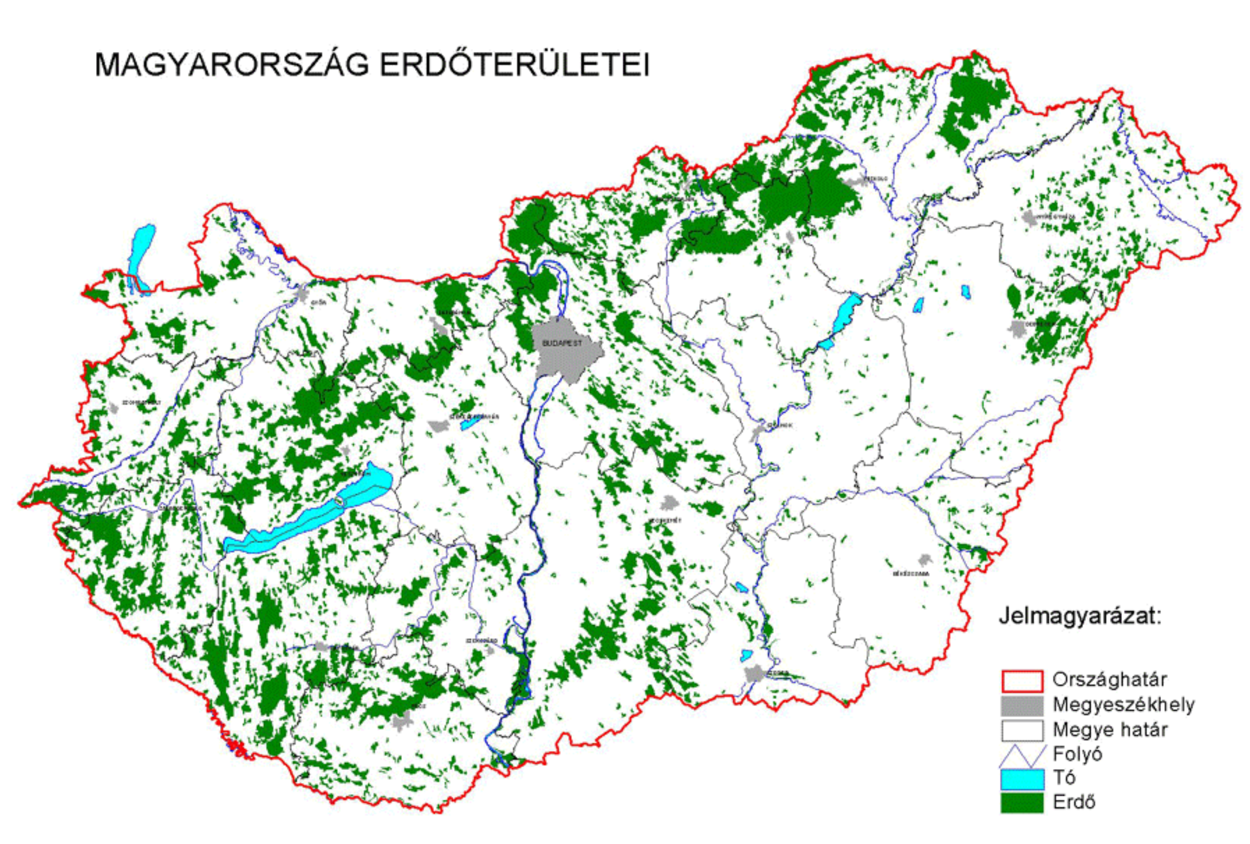


Figure 40: Forest areas of Hungary

In evaluating forest assets, it is important to consider not only growing stock but also the forest as a living ecosystem that plays a vital role in saving and improving the living environment. Within this context, forests fulfill three main functions: production (accounting for 55% of total forest area in Borsod), protection (44%, including the protected areas as well) and only 1% is used for other purpose, such as for recreation, education and research purpose. Still a high share of Borsod's forests is state-owned (64%), whilst 25% is in private hands and only 1% is communal. The ownership of the rest 19% is not structured and ordered. More detailed figures can be seen in Annex VIII. Some 99% of forests are managed under the clear-cut system (62% of seed and 36% of coppice origin). The yearly logging is managed according to the sustainable forestry principle, which is about 500,000 m³. Flow diagram of Borsod's forestry sector has been processed and shown in Figure 41. As can be seen, 60-70 % of the logging wood is used as firewood or for industrial purposes [Winkler,2001], [Bai,2002], and nearly 20% are residues, which mostly remain in the forests or collected by the local population and used as firewood [Èszakerdö,2006]. Use of wood for energetic purpose has several advantages, among others it has long historical experiences, the technology is available and widely used, its ash, S, Cl and K contents are low, it can be produced in areas with various conditions and it is easy to store [Marosvölgyi,2006]. The theoretical potential of the forests in Borsod is about 8,600 TJ [Szarka,2006].

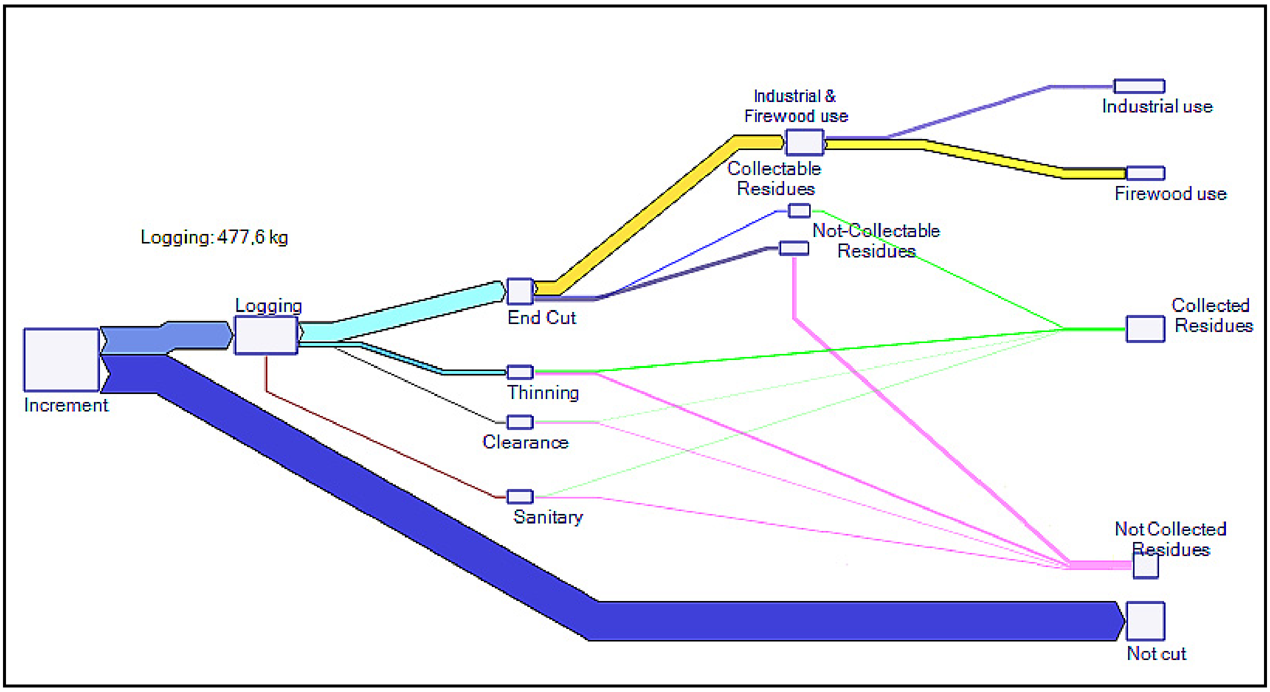


Figure 41: Flow diagram of the use of wood in Borsod's forests (1,000 t)

4.6.3. *Energetic plants and plantations*

Besides traditional agricultural and forestry production, there is a further possible way of biomass generation, represented by energetic plants. Energy crops are biomass derived from either agriculture or forestry used as a fuel or energy source. Taking this into consideration is important, because in case of production of main products for energetic purpose, the costs of the raw materials accuse the energy production, contrary to the use of waste or byproducts, when a significant part of the costs of their treatment, logistics, etc are carried in the price of the main product [Bai,2002]. Agro-energetic plants could contribute to revitalizing the agricultural structure. Energy plants can be classified in different ways, according to their:

- material and main features (arboreal and non-arboreal),
- growing characteristics (perennial and annual),
- future uses (alcohol, oil, biogas, heat),
- being main or byproducts and
- special or facultative purpose.

Energy plants in Hungary are classified as arboreal and non-arboreal plants, for practical purpose. In case of production of **non-arboreal** energetic plants there is a huge number of shoot per hectare, besides it is characterized by a relatively small height, and by the applicability of technological and technical solutions from the agriculture. The following non-arboreal plants are representative in Hungary: (1) perennial: rape, triticale, cannabis and (2) annual: Bromus inermis Leyss, Baldingera arundinacea L., Miscanthus Synensis sp [Bai,2002] (Figure 42).

Energetic arboreal plantations are purpose-plants with the objective of producing a significant amount of dendromass within a short time frame for energy production purpose [Bai,2002]. Among arboreal plants, two further types can be set, namely the **energy forest** and energetic wood plantation. Energy forests are such traditionally managed forests, which yield only limited quantity of logs. Therefore forests with low industrial wood output will be re-qualified as energy forests. The tree-stock will still remain in the forestry division, but their cultivation will differ from sustainable and near-to-nature forest management in many respects, (reduction of maturity age, shoot factory, handling of non-native tree species). Energy forests can be established by either re-qualifying existing plantations, or setting-up new special-purpose forests for fuel production. Their cultivation and harvesting rely on traditional methods and systems, but for the sake of high yields, usually fast growing tree species are selected, and the felling age is shortened accordingly. Cultivation and harvesting rely on traditional methods and systems [Bai,2002], [EC,2004d].

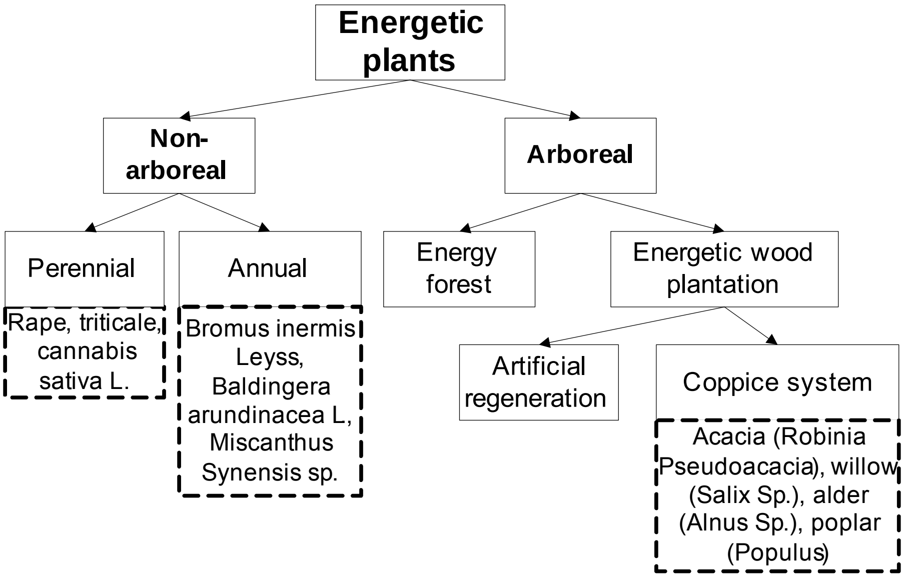


Figure 42: Classification of energetic plants in Hungary with selected examples (based on [Bai,2002])

Energy wood plantations are specifically set up for energy-tree production on fertile lands, regardless of the topography as long as machine harvesting and large scale farming are possible. They are established on agricultural field without changing their legal cultivation class, therefore are considered as agricultural land. Their two modes of operation are artificial regeneration and coppice system.

For artificial regeneration of plants the soil has to be prepared and then replanted with the tree-species of choice after each harvest. Tree-species will be selected based on their yield per hectare under the particular growing conditions. Such plants are cultivated under monoculture conditions and carry a higher stand density then usual ones. Trees are harvested by clear-cutting at the age of 8-15 years and made into standard products like firewood and saw logs. After harvesting has been completed the soil is prepared again and reforested. It can be performed by standard motor-manual equipment. Any tree species, even conifers and exotas can be used, this technology does not require large investments and can be used on a wide variety of terrain. However it is characterized by relatively expensive propagation material and the need for soil preparation after each growing cycle. In Hungary, this form of cultivation will be the most popular among small operators according to studies [Marosvölgyi,2007].

In case of a coppice system the area is planted very densely, about 13,000-15,000 trees per hectare.. Trees are harvested between the age of 3 and 5 and after removing the original stems, trees shoot again from their stumps without special intervention. Trees can be cut periodically in every 3 to 5 years and harvesting can be repeated 5-7 times before replanting. The harvesting technology including the equipment used must be known before planting. In small-scale farming (motor-manual harvesting by power-saws, chopping by mobile crushers) on plantations over 100 hectare, self-propelled chipper-harvester can be used. This form of cultivation has the greatest biomass yield over time. Further information of selected plantations can be found in Annex IX.

4.7. Environment

Existing conditions of environmental media of Borsod County, with special respect on their pollution are included in this Chapter. Air quality, soil, and biodiversity are described and analyzed based on statistical information and environmental county plans [ÖI,1999]. In general, investments in environmental protection show a relatively favorable picture. The amounts invested increased with price, although the increase is more modest if the deflation index is taken into account. The majority of investments are connected to sewage management. Comparison is limited by the fact that since 1999 the contents of investment statistics have changed, thus investments in environmental protection cannot be followed.

From the total **air pollution** of Hungary 15-20% is Borsod's contribution. A critic area is the city-industrial agglomeration of the Sajo valley, where around 90-95% of the pollution is generated. From a health point of view, the loose dust load in populated areas is notable. The effect of the traffic and energy sector is increasingly significant, especially in built-up areas, close to city centers and highways, where the pollution is often close to, or over the limit values. The decline in industrial production starting in 1985, along with technological development, contributed to a positive change towards a cleaner air; but emissions are still considerable [ME,1999a], [ÖI,1999]. The main polluting companies are the ones responsible for energetic and chemical production. The air quality of rural areas is usually good, but in heating season is deteriorating. Among components, the mitigation of carbon dioxide is not only local but a national objective, as well as target of the Kyoto protocol.

Soil conditions, in correspondence with the terrain, climate and vegetation makings show a diversified picture in the county. The Bükk mountains in the area of Borsod county belong to the zones of brown forest soils (Luvisols and Cambisols), what indicate the character of the representative soil types. Besides, a relevant proportion of the area is covered by Luvisols, Lithosols, Gleysols and Leptosols, whilst in the alluvial plain by Phaeozems, Chernozems and Fluvisols. In the mountains the acid brown forest soils (Umbrisols), whilst in limestone surfaces the Rendzic Leptosol is the most characteristic soil. In river valleys Gleysols, while in the floodplains Fluvisols are representative [Dobos,2002]. The transition zone between the plain lowland and the mountains, where the organic materials are more strongly concentrated, is comprised mainly of Luvic Chernozem [Dobos,2000].

About 25-30% of the county is sloping and is endangered by erosion. In these areas the erosion devastates the soil in increased scale, polluting also the surface water, surrounding the eroded areas and depleting the traffic infrastructure. Cultivated land close to the industrial areas are polluted with high historical emissions; in the Sajó valley there have been measurement of high heavy metal content and acidification (ÖI,1999). The most important soil degradation processes in Borsod are the following: (1) acidification – generic process of the decrease of soil pH, especially in the vicinity of industrial areas, due to the air pollution components; (2) wind erosion– especially in the huge arable land during the dry period of summer and autumn. The soil productivity is decreasing; air pollution and the fertilizer particles may generate heath risks; (3) water erosion has been significant in the past decades, especially due to the logging of forests.

Thanks to the habitat variety, Borsod County keep a uniquely rich flora and fauna, having a prominent significance in local, national, European and global scale. The mentioned soil degradation processes, the traffic, industrial pollution, forest logging, intensive tourism, grazing, use of fertilizers in agriculture, mining, etc. endanger this natural value.

4.8. The energy sector of Borsod

Within the description of Borsod, the production, conversion and consumption of various energy sources is apparently the most important contribution. To propose and evaluate future possible alternatives for the use of biomass in energy production, first the past and present energy features must be analyzed in details. Therefore, this section describes the historical and current energy patterns by sectors and fuel types and the future expected changes and potential in BAZ.

4.8.1. Energy production

Energy management in Borsod is characterized by its high dependence on import: 75% of its produced energy is based on import fuels. The own fuels of the county's plants suit less and less to the expectations of economic production, technological development and environmental protection.

Production of energy in general includes all forms of primary, secondary and final energy based on fossil and renewable sources. Determination of the energy production at regional level is a complex task, especially because many data and information needed are not collected, measured or processed in this level (NUTS 3), or they might exist but cannot be gathered rationally due to high costs and complicated procedures. Further general difficulty regarding data about renewables is that it is a recently recognized and investigated sector, therefore methods of data collection, storage and process differ among institutes and databases and their availability is highly limited. Nomenclature of energy sector might also be an obstructive component, since different names, values and explanations are available in different statistics and documents. This work basically considers and applies the European statistics [Mandil,2004] terminology, as introduced in Chapter 2.2, incorporating special Hungarian definitions and other European or international nomenclatures as well. According to these definitions, available data have been collected, calculated and processed for determination of the energy production sector of Borsod County. Both for fossil and renewable sources and their generation into energy are presented in this section.

4.8.1.1. Final energy production

Production and consumption of final energy in Borsod has been calculated based on data from the Hungarian Central Statistical Office (KSH) [KSH,2004b], Eurostat [EC,2005a] [EC,2006b], International Energy Agency (IEA) [IEA,2002a], Energy Centre (EK) [EK,2006c], Hungarian Energy Office (MEH) [MEH,2006], environmental databases (e.g.[Umweltbundesamt,2005]), power producers and distributors [Mavir,2005], scientific literature [Bai,2002], [ÈMÀSZ,2006], [Kaltschmitt,2003] official reports [Drakos,1996], [EC,2004a], conference materials [CEN,1999], [Bohoczky,2005], [Marosvölgyi,2005b], personal plant visits and discussions with experts (Kazincbarcika). Description and results of energy production are summarized in Annex X.

Table 8: Energy production in BAZ in year 2002

Energy production figures	Value
Installed electric capacity, MW	1,402
Power Production GWh/a	3,871
Sold Power GWh/a	3,609
Sold heat, TJ	4,129
Fuel consumption, TJ	44,381
Coal consumption, TJ	13,462
Gas consumption, TJ	12,677
Oil consumption, TJ	12,499
RES consumption, TJ	499
Other consumption, TJ	5,245
Combined produced power GWh/a	543

There are 56 enterprises in Borsod County within the NACE E sector (electricity, gas and water supply) [KSH,2004b], from which 23 is generating energy.

Heat and power production in Borsod are based on three **large power plants**: the Borsod, Tiszapalkonya and AES Tisza (Tisza II) plants, with an overall installed electric capacity of nearly 1,300 MW [Mavir,2005], [MEH,2006]. They are public plants, connected to the power system, which traditionally only have used fossil resources - about 80% of the coal, oil and natural gas in 2004 - representing not only the cost and transport-related further negative impacts, but also high dependency of the county. The big plants produce 2,400 GWh power all together, with changing fuels over the years (see Figure 43), from which 2300 GWh is fed to the national grid [ÖI,1999].

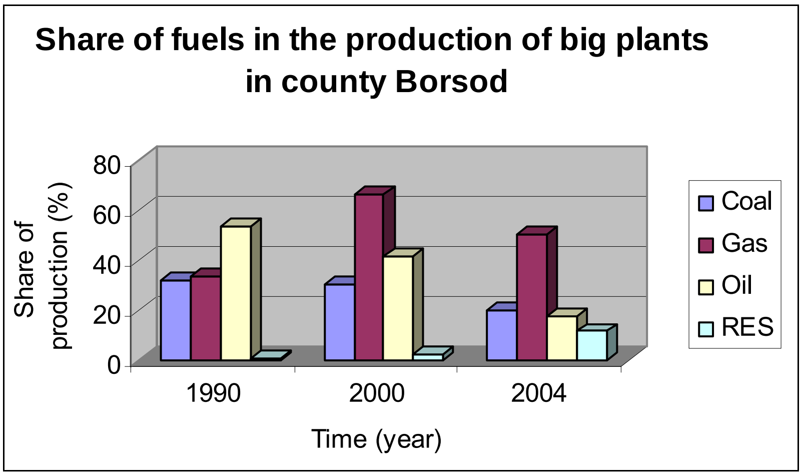


Figure 43: Use of various fuels within power generation in the big plants of Borsod

As it can be seen from Figure 43, the role of gas in power generation was increasing in Borsod, as in Hungary in general after 1990, due to the new connections of numerous private houses in both rural and urban areas. However, oil consumption shows a declined tendency, during previous years. The use of coal will further decrease in the future, and must be therefore replaced by alternative and renewable sources. At the same time a significant development has been realized since 2004, and currently ~8% of the consumption is covered by renewable sources, which are represented by forest wood and residues in the Borsod Heating Power Plant.

The Borsod plant was established between 1951 and 1957 for the use of brown coal stocks of the county and to supply its industrial regions with energy. The power plant provided condensational electricity for the national joint grid system as well as for the surrounding plants, mines and settlements and it also produced industrial steam and hot water for the surrounding industrial buildings and Kazincbarcika city. When its contract-time expired in 2003, energy supply and heating functions of the plant ended. Within the competitive market conditions that were created by the introduction of liberalization in the energy market, the power plant was not suitable in its original form for operating on commercial basis neither from environmental nor from a business-based point of view: available low quality brown coal did not meet the environmental standards because of its high ash and sulphur content, furthermore high fuel costs and low efficiency made impossible to sell the electricity produced [Gács,2006]. At the same time the site's infrastructure and operational facilities of equipments could be converted with relatively low cost making it possible to switch to up-to-date energy production. This conversion was also due to the favorable geopolitical conditions of fuel supply, namely the opportunity to switch to the use of firewood gained during maintenance tasks of nearby forests carried out within the regional forestry-plan. Investment costs of conversion reach EUR 8,5 million. Due to the Joint Implementation Agreement between the Dutch and Hungarian Government 20% of investment is financed by the Dutch partner. 45% of investment sources are guaranteed by investment loans and 23% is covered by a leasing contract. The plant has 137 MW installed capacity and has completed around 340 GWh sold power in 2005 [OPET,2002]. Biomass based electricity production connected to the national grid is 220 GWh/year. For basic fuel supply the Borsod Plant it signed long-term contracts (of 10 years duration) with four state-owned forestry corporations operating in the region. Two corporations located directly in the neighborhood provide 70-80% of the firewood determined in the contract. 90-95% of the forests in northern Hungary have hard crown (oak, beech, turkey oak, hornbeam) whose density may reach 1 t/m3. General humidity of firewood is around 35% with a heat value of 12 MJ/kg. Firewood is delivered by road transport or railway to the plant. Delivery distance is 40 km in average but a smaller amount (3-4%) is transported by railway from more than 200 km. According to the contracts 170-270,000 tones of fuel is delivered annually by the forestry corporations. Further 20-80,000 tones of firewood is expected from other suppliers. Amount of sawdust is about 30-40,000 tones and about 20,000 tones of sunflower shell is fired as well [OPET,2002]. Two significant plants are planned to close in

2012 and 2013, which also calls the attention for seeking future possible alternatives to supply the energy demand of Borsod County.

Besides the three big plants there are 23 small plants in Borsod (in 2004) using gas, coal, oil or renewable sources (water or wind). The ones using fossil sources are industrial plants providing 96% of the 625 GWh power generation, and about the same share of the 2,100 TJ heat production. Further description of most important plants is given in Chapter 4.8 and in Annex X.

The role of renewables in the energy production has been increasing the past years in Borsod, as described previously. Currently three small-scale (0.5-10 MW) and three micro **hydro** power plants (<0.5 MW) were installed in the Hernád river with a total capacity of 5.4 MW. The plants are running from the beginning of the 20th with about 36 % efficiency and 5,000 operational hours yearly [Göõz,2006] [Mavir,2005] Their total energy production in year 2006 was 104 TJ [Schmidt,1999], the distribution of which is demonstrated in Figure 44. In the Hernád river further plants with 1,000-1,800 kW capacity are planned to be built in the near future [Schmidt,1999]. Utilization of **solar** energy is only known in a heat plant in Miskolc with a capacity of 246 GJ/year.

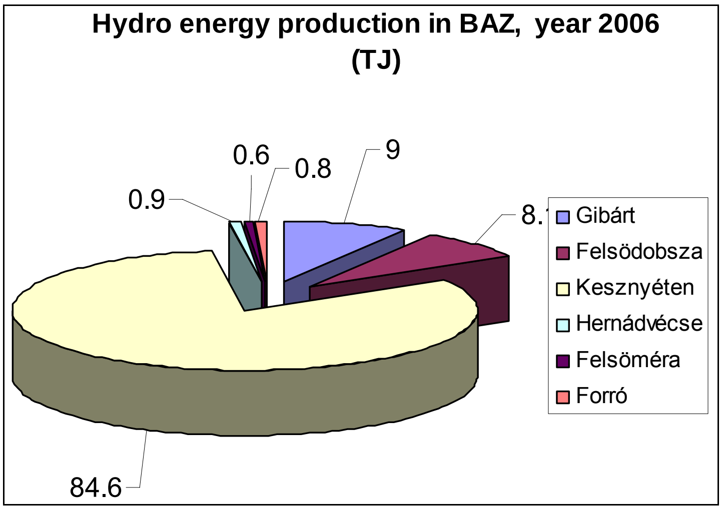


Figure 44: Distribution of hydro energy production in the settlements of Borsod county (year 2006) [Schmidt,1999]

In Borsod there is a 3.5-4 m/s average wind velocity at 50 m high, which is the Hungarian average [Radics,2004]. In the 19th century there has been a few **wind** mill running in Borsod county [Tar,2005b]. However, the potential has not been exploited until the near past [Bartholy,2003], but the first wind power plant was built in 2004 with 225 kW (in Bükkaranyos) and since 2006 only one more is operating with 2,000 kW in Felsőzsolca [Tóth,2005b]. In the future further plants are expected to construct.

Setting the figure for biomass production is complicated because they are only part of a much larger production for non-fuel uses. The heat and electricity generation based on biomass is given first within this study, then its potential from agricultural and forest sectors, and finally the use of biomass by all sectors.

4.8.1.2. Primary fossil fuels

Fossil energy sources include crude oil, natural gas and solid fuels (coal and its derivatives). Statistics about fossil fuel sources can only be found at country level in the official Hungarian statistics [KSH,2005a], whilst the county-level data are only nominal and economically expressed data. In order to gather further historical data of production and spatial location of the quarries in Borsod, related scientific local journals have been reviewed for specific articles [Schmotzer,2004], [Kontsek,2004], [Kárpáty,2004], universities performing related studies [Szilasi,2006] and responsible of mines, as well as the Mining Bureau of Hungary (MBH-Magyar Bányászati Hivatal) have been contacted. In this way the fossil fuel production for the time period of 1990-2004 could be calculated for Borsod. According to this investigation it can be stated that historically the region of Borsod was an important area for fossil energy sources. High quality brown coal and lignite production fields are located in the Mátra and Bükk mountains [Kontsek,2004], [Schmotzer,2004]. During the 80-90's over $4x10^6$ tons good quality brown coal and lignite was exploited yearly, an amount which continuously declined over the last decades, presented in Figure 45.

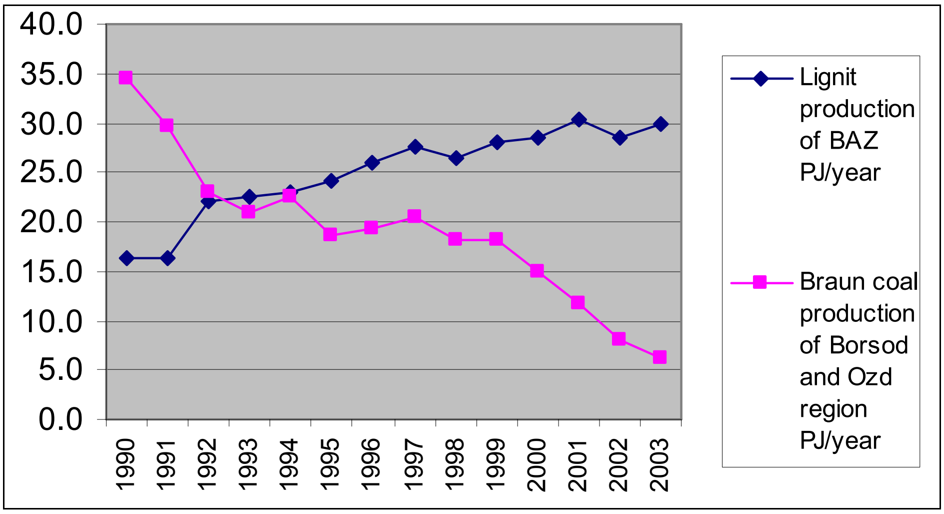


Figure 45: Historical lignite and high quality brown coal production in Borsod

Nowadays there is only exploitation of lignite, with a yearly production of $3.5x10^6$ t in Borsod. Oil and natural gas resources cannot be found in the county. In general, according to estimations made by [Kárpáty,2004] the future supply of fossil sources will decline in Hungary (see Table 9), which trend is expected in Borsod as well.

Table 9: Future estimated fossil resource supply of Hungary [Kárpáty,2004]

Source	Industrial assets (Mt)	Supply a (year)	Supply b (year)
Crude oil	22.2	18	21
Natural gas	67.1	18	21
Black coal	197	14	?
Brown coal	193.9	16	30
Lignite	2,949.80	80	100
CO_2 gas	32	100	100
Bauxit	39.1	5	54
Manganese ore	0.3	6	6
Non-metal mineral resources	9,109.40	100	100

a=considering the working mines
b=considering the whole industrial assets

4.8.1.3. Potential of biomass

Attempts to measure the potential of renewables are complicated by the absence of clearly defined production points. Since this study considers the biomass among RES, the estimation of its potential from the agriculture and forest sectors is presented below. By analyzing the energy potential of a region, the region's energetic resources can be opened-up, which might serve as basis for future use and development alternatives in the field, as well as various scenarios can be defined with their advantages and disadvantages [Iparterv,1998]. In Hungary, 11 out of the 19 counties have relevant biomass potential, according to the studies of Bai [Bai,2001]. Among them, the forest biomass has a significant potential in Borsod, shown In Figure 46 (the size of symbols represents the importance of the biomass type in the region and relative term, comparing to the others).

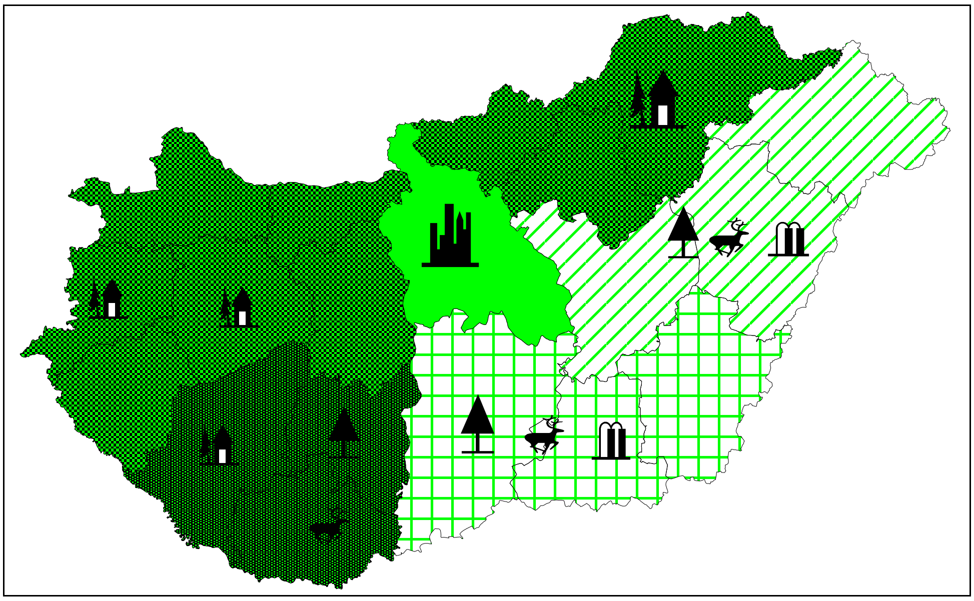


Figure 46: Sectoral and regional biomass potential in Hungary [Bai,2003]

Comment: :animal livestock :plant production :Forestry :Communal : Food industry

The local energy sources of a region are determined by the geographical, geological, climate and settlement structural conditions, economic, social and political environment, as well as the energy consumption patterns, and technology available [Àrpási,2006]. In general it can be stated that the renewable energy sources are low-density sources, therefore their local utilization has a real contingent, which must be investigated for each conditions uniquely. Generalization can be allowed only in the selection of methods applied is general. Besides local circumstances the national conditions also must be investigated, as well as the natural conditions since biomass use requires a closeness to the nature [Hoogwijk,2006]. The factors affecting the effective use of biomass are summarized below:

1. Geography and natural resources
   1.1. features of the land cover (share of mountainous areas, soil quality, forest, etc.)
   1.2. land use characteristics (agricultural, industrial, etc. use)
   1.3. soil type [Unk,2005]
2. Economic and political conditions
   2.1. prices of fossil fuels and of nuclear energy
   2.2. external (environmental) costs of energy production
   2.3. governmental or other support
   2.4. international programs commitments (EU-directives, Kyoto-Protocol)
   2.5. international/national/regional strategy, concepts and set objectives
   2.6. regulative measures (takeover prices, trends, tax reductions, quota etc.)
3. Technology
   3.1. capacity and existing system facilities
   3.2. technological plans
   3.3. efficiency comparison with conventional energy technologies
4. Social environment
   4.1. energy consumption patterns
   4.2. social awareness
   4.3. local forbearance against new biomass solutions

Potential of RES can be classified as theoretical, available and technical potential (see also Figure 47) [Konrad,2003], [Pröbstle,2006], [Westergrad,2002], [Szarka,2006], [Marosvölgyi,2000], [Barótfi,1998]. Estimations of availability begin from the **theoretical potential**. It is the total physical offer of renewable energies within an area, without considering any limitations about the use. In this case that represents the total amount of biomass resulting from both agriculture and forest sectors. The theoretical potential serves as an absolute physical upper limit for the analyzed resource; however for a practical use it is often too high. There, a more realistic potential has been analyzed, called **available potential,** referring in current study to the annual growth of the analyzed sectors. Finally the **technical potential** is a proportion of biomass available reckoning technical conditions and structural restrictions [Neubarth,2000].

Theoretical potential	Physical offer of biomass without the effective limitations	Amount of biomass in the total agricultural and forest areas
Available potential	Availability of natural resource	Growth of forest and agricultural products
Technical potential	Practically usable potential	Products/byproducts collectable, not used for other purposes and feasible

Figure 47: Levels of potential for assessing biomass availability

There are several biomass types suitable for energetic use, however not all have an important potential in Borsod. Selection of the studied crops was made based on the natural conditions and the structure of the agricultural and forest production within BAZ as well as on relevant Hungarian literature [Tar,2005a], [Bai,2002], [Barótfi I.,1998b], [Fogarassy,2001]. Furthermore data for the analysis have been collected via interviews with forestry institutes and companies [ÀESZ,2006], [ÀESZ,2002], [Èszakerdö,2006]. Figure 48 displays the considered biomass sources grouped by sectors and by the utilization purpose. Afterwards, methods for calculating potential of biomass for energetic purpose from the agricultural crop, animal, forest and energy crops sectors are presented, including the data and information sources and numerical results as well.

Forest-origin biomass potential

Many technological, socio-economic and environmental factors affect the availability of forest-origin biomass:

- Price development of alternative fuels, taxes and subsidies
- Development of procurement technology and logistics
- Motivation of forest machine and truck contractors to participate in business
- Development of the quality requirements of forest chips
- The acceptance of private forest owners, which is affected by the price paid for biomass
- The energy and climate policies at the national and EU levels[8] [Könighofer,2001]

The forests in Hungary are managed according to the sustainable forestry principle, as, described in Chapter 4.6.2, which fosters the growing of area and stock. For this purpose extracted wood material is not allowed to exceed the yearly increment. Thus, the yearly gross increment has been considered as the upper limit for forest wood utilization. The size of the county's forest land and the average annual specific increment has been used to calculate the available potential and to express it in energy unit.

The county of BAZ comprises large areas of forests especially with species of oak, beech, hornbeam and robinia, with more than 180,000 ha (see Chapter 4.6.2) The yearly growth (377,000 m^3) is decreased by several factors, e.g. industrial wood use, clearance, thinning, sanitary and other ways. The available energetic potential of forest wood reaches 8,700 TJ [Szarka,2006], whilst the currently used firewood amount is about 2,000 TJ. The additional technical potential based on this calculation is resulted from the not extracted but possible, according to the sustainable forest management, and the amount of not collected, but economically possible residues, which is almost 4,500 TJ. Results are shown in Figure 49, whilst the procedure is presented in Annex XI.

[8] The trade of CO2 emissions will be of utmost importance, among others.

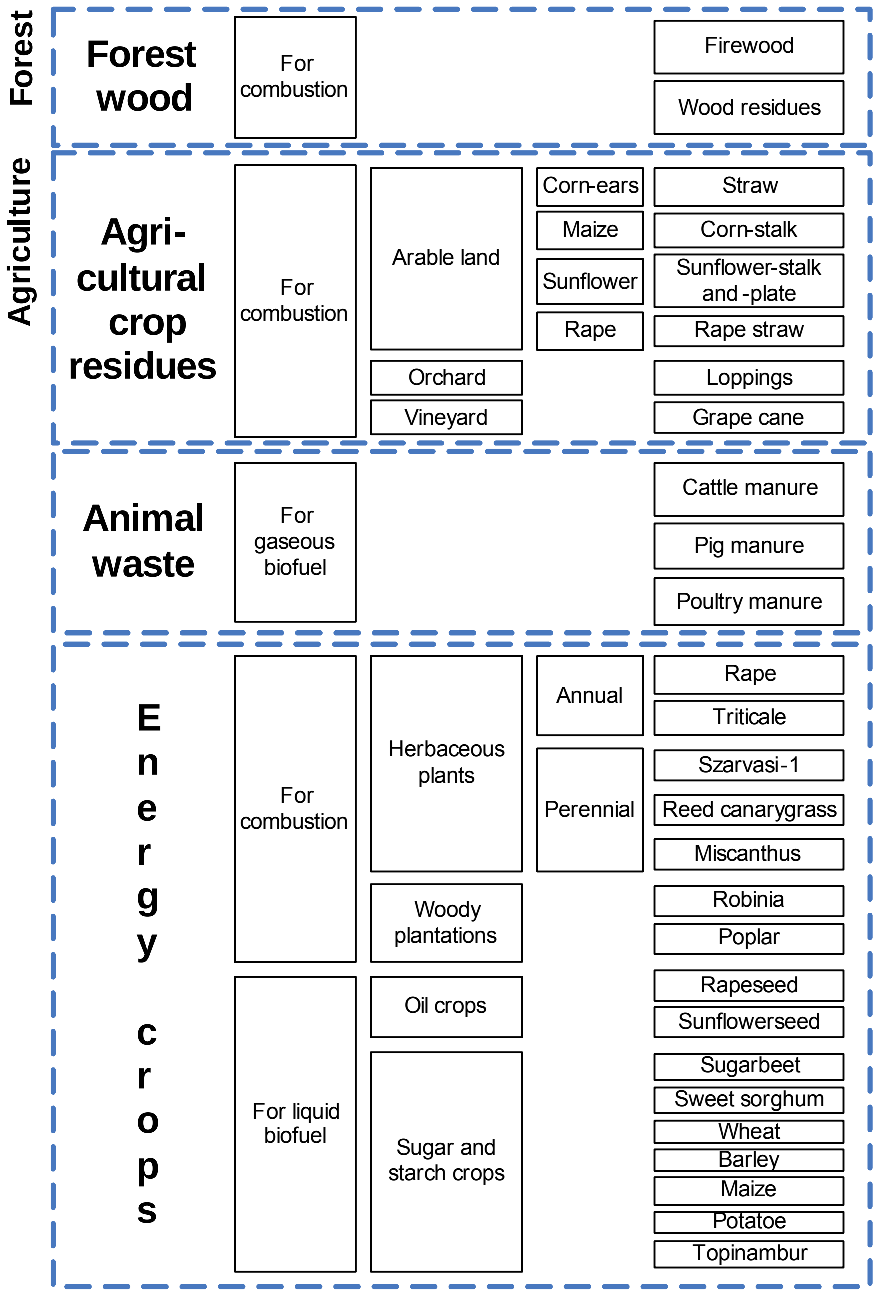


Figure 48: Selected boundaries of the biomass potential analysis in BAZ

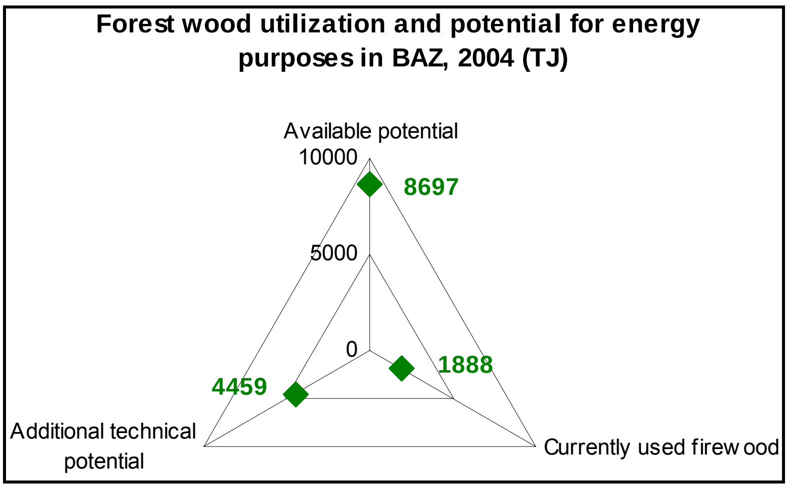


Figure 49: Used and potential wood material for energy in BAZ in 2004

Agricultural crop biomass production

Agriculture is one of the main sources where biomass is produced, both from crop and animal production sectors. For determination of crop production, time-series data are needed, such as the size of agricultural area, their type of cultivation and produced quantities. The sources used to determine those data from Borsod were the Hungarian and regional statistics [KSH,2004a], [KSH,2003], [KSH,2000], [KSH,2004b] and satellite images [EEA,2000]. For the determination of the quantities and energetic values of yield of residues and animal manure, there is no existing statistics for county level, therefore European and related Hungarian literature, as well as previous analysis and researches have been reviewed [Barótfi I.,1998b], [Fogarassy,2001], [Bai,2003], [Kaltschmitt,2003] and implemented, furthermore energetic programs and research works of other counties [Iparterv,1998], [Àrpási M.,2006]. The estimation of the energetic potential of selected crop residues is based on the cultivated area or the agricultural production for each crop and average residue to product ratios or residue yields per hectare, given in fresh tons by harvest. The theoretical potential has been calculated by multiplying the annual residue amounts (t/ha) with the relevant heating values referring to fresh mass (MJ/kg) (see Table 10).

Table 10: Basic data for the calculation of agricultural crop residues potential in Borsod in 2004

Denomination	Crop land	Average yield	Residue to product ratio	Yield of residues		Source
	ha	kg/ha/a		t/ha/a	t/a	
Corn-ears	16,912	4,629	1	4.6	78,277	[KSH, 2004b], [Bai, 1998]
Maize	34,456	6,740	1.8	12.1	418,020	[KSH, 2004b], [Fogarassy, 2001]
Sunflower	38,102	2,350	2	4.7	179,079	[KSH, 2004b], [Barótfi et al., 1998]
Rape	16,945	3,050	2.9	8.8	149,879	[KSH, 2004b], [Fogarassy, 2001]
Orchard	7,218			2.5	18,045	[KSH, 2004b], [Bai et al., 2002]
Vineyard	8,697	6,700		1.8	15,655	[KSH, 2004b], [Bai et al., 2002]

The availability of the byproducts for energy purposes is restricted by several technical, environmental and economic factors that are difficult to be quantified. The calculated technical potential takes into account the exploited residue quantities for non-energy (e.g. animal feeding, littering) or traditional energy applications and the availability of the free amounts depending on the farm size. By field crop byproducts it has been assumed that 35% of the free residues can be exploited from small farms (considered as identical with private holdings) and 65% from big farms (assumed to be represented by agricultural enterprises). In case of lopping and grape cane the factors of 33% (small farms) and 100% (big farms) have been applied [Iparterv,1998]. County yearbooks were used to derive the distribution of agricultural enterprises and private holdings by crops within BAZ [KSH,2004a], [KSH,2004b].

On the whole, it has been found that straw of corn ears and corn-stalk arise in the greatest amount in the region – above 400,000 tones -, followed by sunflower and rape residues, whilst lopping and grape cane quantities with about 20,000 tones are less important (see Figure 50). The distribution of the cultivation areas is so well reflected except in the case of maize. Besides the great residue to product ratio, corn-stalk has actually high moisture content when harvested. In turn, corn stalk has lower heating value, which is represented by its significantly lower theoretical potential compared to corn-ear straw. As Figure 51 presents, theoretical potentials range from 172 up to 7,216 TJ. Collectable by-product amounts and technical energy potentials by each residue types show smaller variance within the range of 72-1,428 TJ.

Agricultural animal biomass production

The average volumes of animal manure largely differ among animals and mainly depend on their age and life weight [Steffen,1998]. Design and operation of manure collection, storage, pre-treatment and utilization systems for livestock enterprises have been investigated to gather detailed data [Nikolaou,2003] [GYMSA,2005]. Biogas yields and the energy content of biogas have been taken from literature [Iparterv,1998], [Barótfi,1998]. The calculation process was performed as follows: the number of the animals (piece) has been multiplied with the yearly average manure yield expressed in tones of dry organic matter (DOM) (t DOM/piece/a) and the biogas yield per unit of DOM (m^3/t DOM). The theoretical potential of animal waste refers so to the energy content of the biogas, which can be produced from manure. By determining technical biogas potential it was assumed that manure can fully be collected from agricultural enterprises (regarded as big farms) but it can not be gathered from private holdings, which mainly raise some piece of animals only and usually use the arisen manure for dressing their fields. The ground for the calculation is the number of animals and the annual arising manure within the county summarized in Table 11.

Table 11: Livestock size and manure quantity in county BAZ in 2004

Animal type	Piece	Animal manure, t DOM/a
cattle	38,000	66,576
of which: cow	20,000	35,040
pig	106,000	14,702
poultry	2,090,000	22,123
Total	**2,234,000**	**103,401**

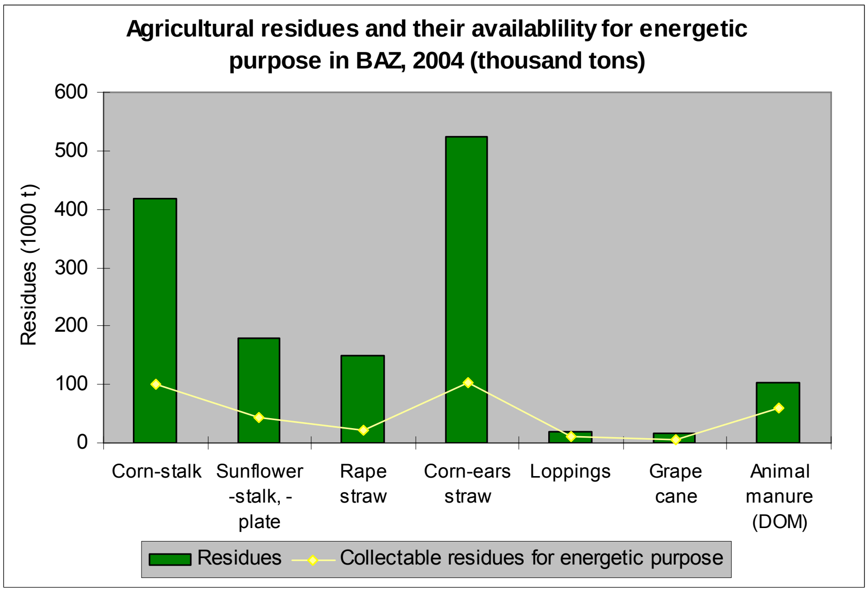


Figure 50: Arising and collectable agricultural residues potential for energetic purpose in Borsod (2004) (own calculation)

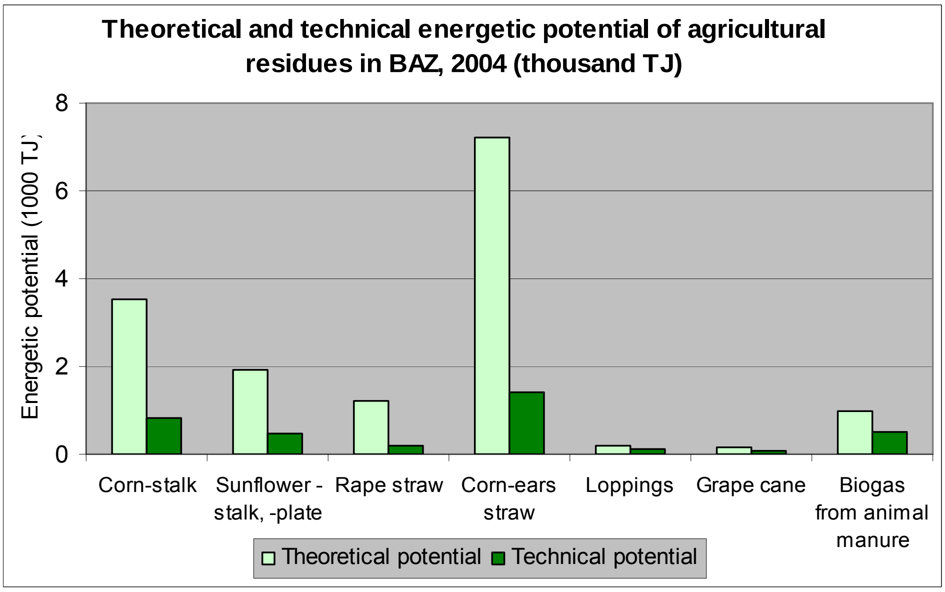


Figure 51: Energetic potential of agricultural residues in BAZ in 2004 (own calculation)

Potential of energetic crops

As it is shown in Figure 48, energy crop potential has been analyzed under two perspectives regarding the utilization purpose: crops potential for combustion and for producing liquid biofuels (biodiesel and ethanol). The selected crop types are considered to be the most suitable ones in Hungary, reckoning water, soil and climatic requirements, yield and energy content as well as availability of cultivation and conversion technologies. In some cases further attempts are needed such as by the combustion of triticale to generate heat [Bai,2002].

In general, it is assumed that energy crops will be cultivated on low-quality arable land with low financial returns and on set-aside land. Definition of low quality land in Hungary is based on the Hungarian classification, so called Arany Korona (AK) or Gold Crown. The AK classification has been established between 1876-81 and represents the total yield of one hectare agricultural area, incorporating the soil quality, weather conditions as well as the future expected costs and prices. Some studies classifies areas with less than 17 AK already with low quality. Based on the AK, a proposal of possible use of different plant types can be made, what is summarized in Table 12.

Table 12: Possibilities to produce biomass according to the soil type (Horvath, Bai)

AK	Biomass
0-12	Favorable areas for biomass production and for energetic plantations in general
0-16	Appropriate for intensive crop production and horticulture, biogas production
8-23	Arable crop production is proposed. Within the crop rotation it is possible to plant plants which is supported and biodiesel or bioethanol
9-24	Appropriate for maize production for bioethanol

Data on the available set-aside areas in BAZ have been derived from county statistics [KSH,2004b], whilst the determination of low-quality arable land rests on the study of [Kovács,2006], according to which half of the arable areas in the region have unfavorable parameters and their use for producing traditional crops is not rentable. Several other data sources and scientific literature serve as basis to derive the crop and biofuel yields and heating values [Bai,2002], [Barótfi,1998], [Janowszky,2005], [Barótfi et al.,1998;Göõz,2006;Janowszky,2005], [Kübelsbeck,2004], [Barótfi,1998]. The calculation process has been achieved as next: the size of the defined cultivation areas has been multiplied with the crop yield and has been expressed in energy unit using heating values. By oil, sugar and starch crops biofuel yields have been applied referring to unit crop amounts. The energy content of the producible biofuels result in the theoretical potential.

As possible cultivation sites of the energy plantations set-aside areas (79,241 ha) and low-quality arable land (131,744 ha) have been considered. One section of the calculation table with the input data (crop land, average yield), intermediate results (crop amount) and outcomes (energy value in TJ per year) are shown in Table 13. Graphical representation of the theoretical energy potential of all studied energy crop types can be seen in Figure 52 and Figure 53.

As result it can be stated, that the most heat energy can be exploited if producing Miscanthus energy grass followed by Szarvasi-1. Concerning the theoretical biofuel potential, the energy content of the producible ethanol is generally higher than that of the extractable biodiesel. Among crop types sugar beet, sweet sorghum, topinambur and maize is the descending order regarding ethanol yields; whilst rapeseed has the greatest biodiesel potential. It is essential to remark, that theoretical potential has to be regarded as informative, because several other aspects can also be taken into consideration, such as other demand for crops, characteristics of the cultivation site, costs, possibilities of technology application, environmental impacts, etc.

Table 13: Calculation of the theoretical potential of energy crops on low-quality arable land in BAZ (Own calculations)

II. a.) For combustion	**Crop land ha**	**Average yield t/ha/a**	**Crop amount t/a**	**Energy value MJ/kg**	**TJ/a**	**Source**
Herbaceous plants						
rape (whole plant)	131,744	5.5	724,592	15	10,869	[Bai et al., 2002]
plant]	131,744	10	1,317,440	15.5	20,420	[Bai et al., 2002], [Gőgös, 2005]
Szarvasi-1	131,744	16.5	2,173,776	16	34,780	www.energiafu.hu
Reed canarygrass	131,744	12.9	1,695,545			[Janowszky, 2005]
Miscanthus	131,744	22.5	2,964,240	17.5	51,874	www.hybys.hu
Woody plantations						
robinia	131,744	11.5	1,515,056	19	28,786	[Bai et al., 2002]
poplar	131,744	11.5	1,515,056	19	28,786	[Bai et al., 2002]

II. b.) For biofuels	**Crop land ha**	**Average yield t/ha/a**	**Crop amount t/a**	**%**	**Biofuel yield t/a**	**l/a**	**Energy value MJ/l**	**MJ/kg**	**TJ/a**	**Source**
Oil crops										
rapeseed	131,744	3.1	401,819	34%	136,619			37.3	5,096	[KSH, 2004b], [Bai et al., 2002], [Chiaramonti et al., 2003]
sunflowerseed	131,744	2.4	309,598	34%	105,263			37.3	3,926	[KSH, 2004b], [Bai et al., 2002], [Chiaramonti et al., 2003]
Sugar and starch crops										
sugarbeet	131,744	60.6	7,988,956	7.6%	607,161	769,531,899	21.3		16,391	[KSH, 2004b], [Kübelsbeck, 2004]
sweet sorghum	131,744			5400		711,417,600	21.3		15,153	[Bai et al., 2002], [Kübelsbeck, 2004]
wheat	131,744	4.9	638,958	29%	185,298	234,851,630	21.3		5,002	[KSH, 2004b], [Kübelsbeck, 2004]
barley	131,744	4.4	579,674	29%	168,105	213,061,272	21.3		4,538	[KSH, 2004b], [Kübelsbeck, 2004]
maize	131,744	6.7	887,955	33%	293,025	371,387,839	21.3		7,911	[KSH, 2004b], [Kübelsbeck, 2004]
potatoe	131,744	18.0	2,368,757	7.9%	187,132	237,175,935	21.3		5,052	[KSH, 2004b], [Kübelsbeck, 2004]
topinambur	131,744			4230		557,277,120	21.3		11,870	[Barótfi et al., 1998]

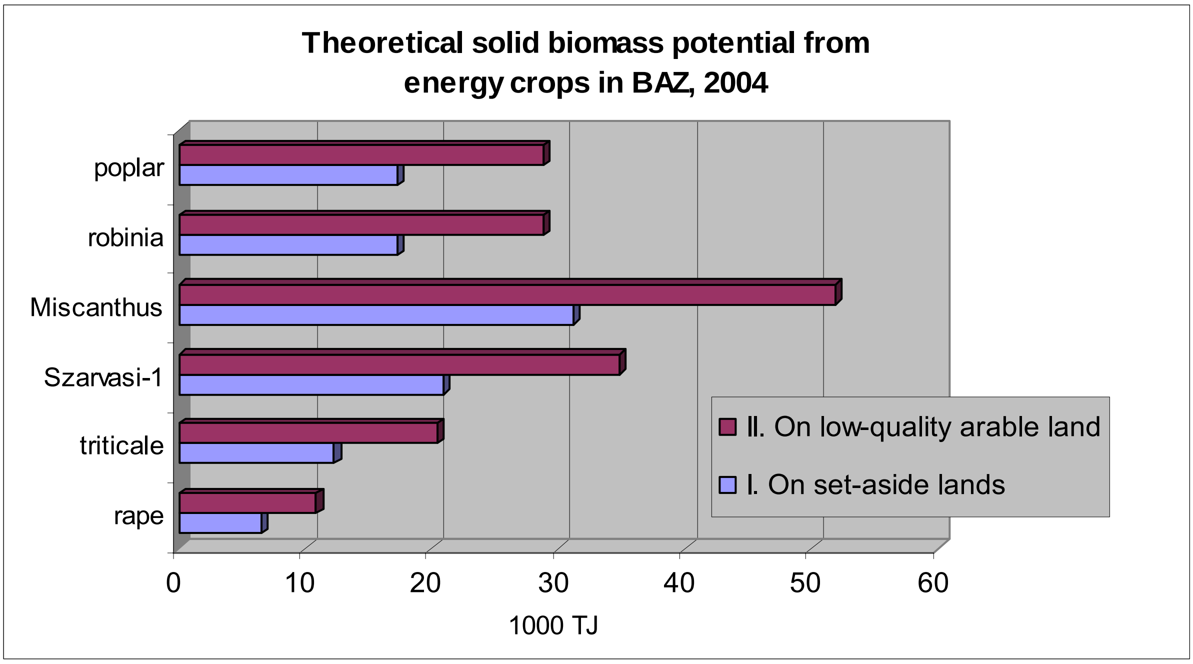


Figure 52: Theoretical energy potential of energy crops produced for heat purposes on set-aside and low-quality arable land in County BAZ

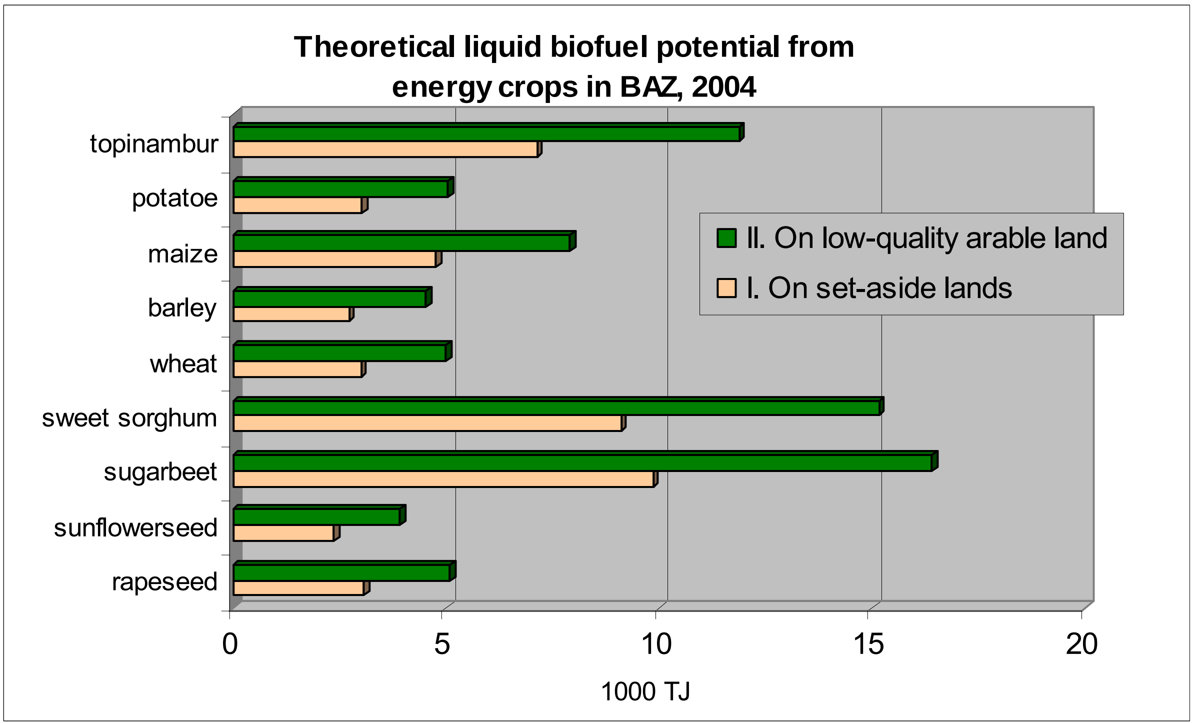


Figure 53: Theoretical energy potential of liquid biofuels produced from energy crops cultivated on set-aside and low-quality arable land in County BAZ

4.8.2. Energy demand side analysis

Information about consumption of energy by sectors and fuels is hardly to be found at county level in Hungary. Data gathering, structuring and processing have been performed with stakeholders' participation and based on existing methods of the Energy Center (EK), Hungarian Energy Office (MEH) and Hungarian Statistic Office (KSH).

The resulted final consumption of energy covers their use for heat and for non-energy purposes. Fuels used for electricity and heat generation, as well as the quantities of the energy produced, are excluded from final consumption and accounted for transformation. The final consumption is the sum of the non-energy use and consumption by the end use sectors agriculture, households, industry, transport, trade and services [Mandil,2004].

Before presenting the results of sector consumption, the investigations and resulted nomenclature of economic activities will be introduced. Most of economic statistical data in Hungary are given according to the NACE distribution of the European Community [EC,2007f]. But since Hungary is member of the EU only since 2004, some classifications are given by the Hungarian standard. Example of which is the energy consumption, categorized by the Hungarian Standard Industrial Classification of All Economic Activities [KSH,2005a]. Therefore, Hungarian classification used in the national energy balances had to be transferred into one system conforming to the NACE, for which the method was provided by the EK, presented in Table 14. The electricity and gas consumption of the summarized sectors are than presented in Figure 54a and Figure 54b.

Table 14. NACE correspondence with final end user sectors in Hungary (own work)

NACE revision 1.1	Sector
C+D+F (excl. CA, DF)	Industry
I 60, 61, 62	Transport
P 95	Households
41,50,51,52,55,63,64,65,66,67,70,71,72,73, 74,75,80,85,90,91,92,93,99	Trade and services
A	Agriculture, forestry

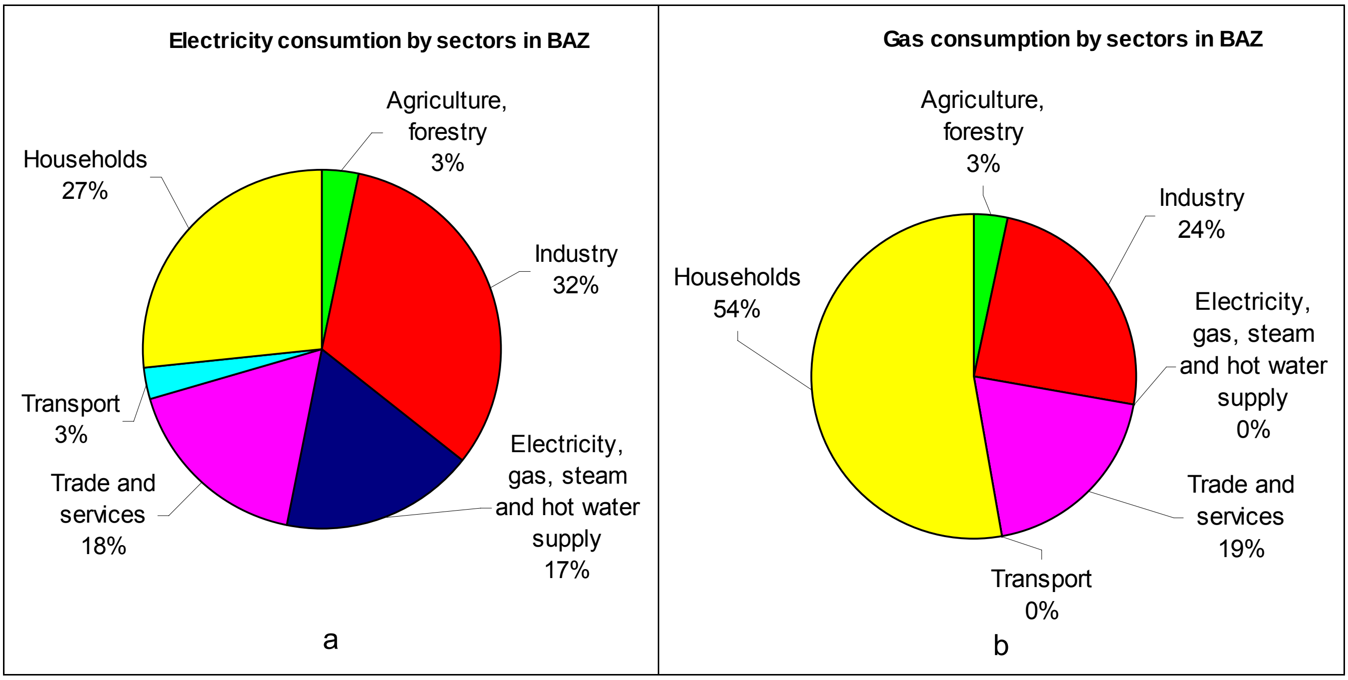


Figure 54: Electricity (a) and gas (b) consumption in county Borsod
Source: [KSH, 2004b] and own calculation

Interpreting Figure 54 it can be stated that industry and households represent almost 60% (32% and 27% respectively) of the whole electricity consumption in BAZ. Nearly the same share (54%) is credited to the households when analyzing the gas consumption. The energy suppliers have also a relatively high share among electricity use (17%) partially due to the low efficiency. The share of agricultural sector fall to 3% of the total consumed energy, especially due to the decline of the production. The share of consumption by fuel types is represented in Figure 55. Examples for calculating consumptions in various sectors are presented in Annex XII.

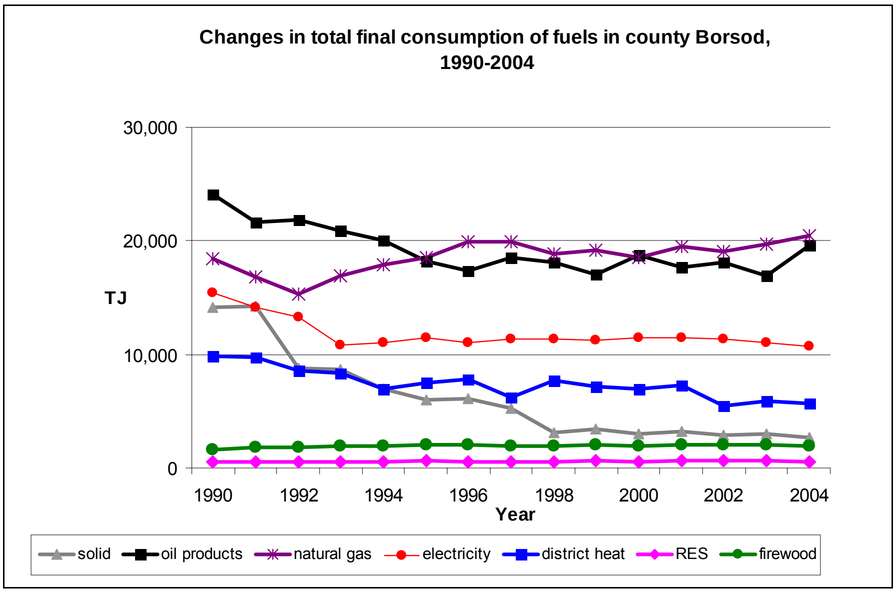


Figure 55: Total final energy consumption by fuel types in Borsod County

4.8.2.1. *Agricultural energy consumption*

Consumption figures in the agricultural sector at county level cannot be found in the statistics of Hungary. Therefore, first Hungarian energy balance figures have been conducted and viewed [EK,2006a]. To perceive the method applied there, responsible persons of the Energy Center and KSH have been contacted. As common agreement with experts, the specific agricultural energy consumption figures used to calculate the national consumption by fuel types [EK,2006c] have been applied to Borsod county as well. Resulted consumption is shown in Table 15, whish data were multiplied by the agricultural area of BAZ to get the total consumption of the agricultural sector (representing NACE A) by fuel types, as shown in Figure 56. This estimation method, however, neglects the integration of factors, such as differences among agricultural activities or energy intensity among regions, therefore they must be taken as informative. However, comparing them with data of the 'Sector Environmental Indicators' [KSH,2005b] results can be considered reliable.

Table 15: Average agricultural energy consumption in Hungary

Energy consumption per hectare of agricultural area in 2004 (TJ/ha)	
Total	0,00446
Solid fuels	0,00004
Oil Products	0,00201
Natural gas	0,00152
Electricity TJ	0,00066
Derived heat	0,00000
RES	0,00002
Firewood	0,00020

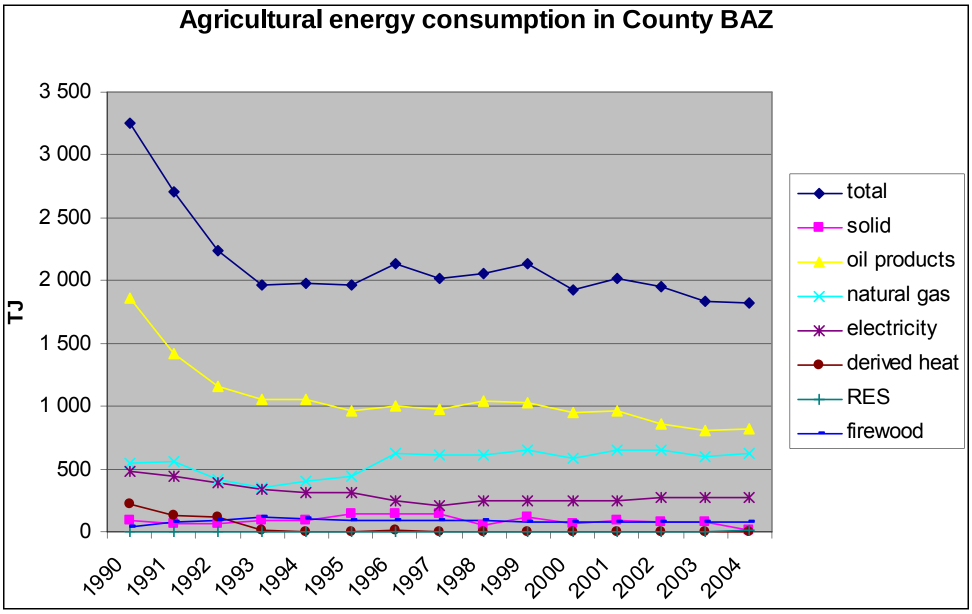


Figure 56: Agricultural energy consumption by fuel types in Borsod

Figure 56 represents a declining energy consumption in Borsod over previous years. Most significant fall of consumption is observable after the political change (1989). The relevance of renewable sources is still low, however the 22 TJ in 1990 increased up to 90 TJ in year 2004 (90% of which is firewood).

4.8.2.2. *Consumption of households*

Both in Borsod and in Hungary the households spends more than 8% of their income for covering their energy demand, due to the relatively high prices of imported fuels, low income and unfavorable energy efficiency [Bai,2002], [Stumphauser,2001]. The dynamic changes of the household's energy consumption are shown in Figure 57. Real time-series data for that could be found only on electricity and natural gas use in the statistical yearbooks for BAZ [KSH,2004b]. The energy amount of district heat consumption was calculated from the energy balance data series at country level, obtained from the EK [EK,2006a]. The calculation base was the ratio of the dwellings connected to district heating in BAZ, comparing to the Hungarian data (KSH and Eurostat). Data on the dwellings' distribution by heating material were given from the database of the Hungarian Population Census 2001 [KSH,2002]. Most conspicuous changes took place in piped gas consumption [NORDA,2006]. Building a new gas pipeline in Hungary in year 1995 resulted in an increase of household's connections [Gy.Matolcsy,2001].

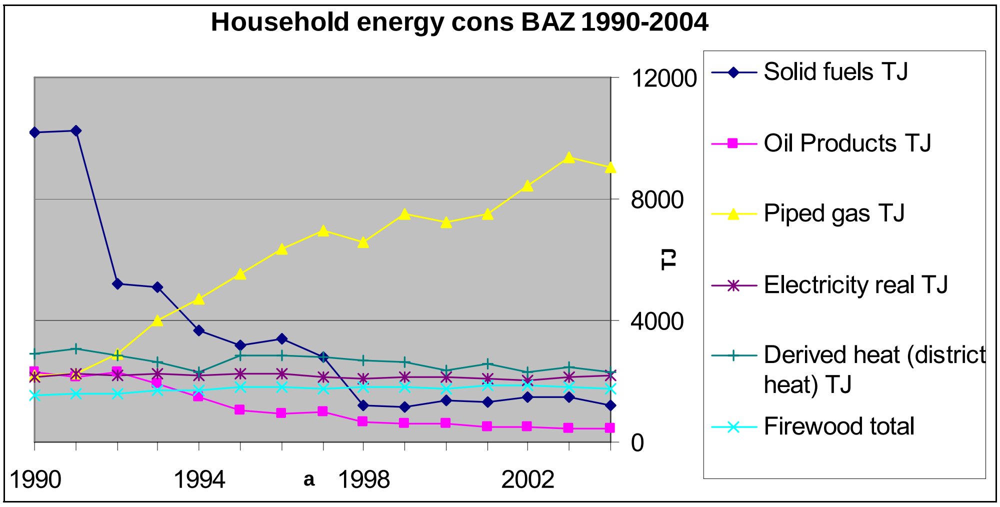


Figure 57: Energy consumption tendency in Borsod's households sector

4.8.2.3. Industrial consumption

Consumption figures of the industrial sector were calculated in a complex way according to fuel types. Use of solid fuels and oil products were estimated for each industrial sub-sector with the value added (VA)-ratio between BAZ and Hungary from country level (based on the national energy balances). This method has been formulated based on the IEA Indicator Approach [IEA,2004], analyzing energy end-use trends. It is made by distinguishing among three main components affecting energy use: activity levels, structure (the mix of activities within a sector) and energy intensities (energy use per unit of sub-sectorial activity). For the sectors services and industries VA measures are applied for all three components. VA is therefore a representative factor for the characterization of various energy figures, also applied within this study.

As the amount of total supplied electric energy and piped gas is yearly registered by the Hungarian Central Statistical Office at county level [KSH,2004b], industrial electricity and natural gas consumption was calculated by subtracting the consumption of the other sectors from the total supplied amounts in BAZ.

Derived heat use of industries was assumed to reach 15% of the total national industrial heat consumption, taken into account that the county had and has a large industrial sector with relatively low energy intensity in comparison to other regions of Hungary [MEH,2006]. As the result of estimations, the changes in the consumption structure between 1990 and 2004 can be observed in Figure 58. The important and continuous decrease is primarily due to the industrial restructuring brought by the political system change in Hungary in 1990, but also the spread of better technologies and decreasing energy intensity play a role in this.

Some deviation between the methodology of the national and county balances is caused, as for the sake of simplicity, consumed energy by the CA 10-12 (Mining and quarrying of energy producing materials) and DF 23 (Manufacture of coke, refined petroleum products and nuclear fuel) categories of NACE was included for BAZ into the final energy use of the industry, even though they belong to the own consumption of the energy sector, but the difference can be neglected.

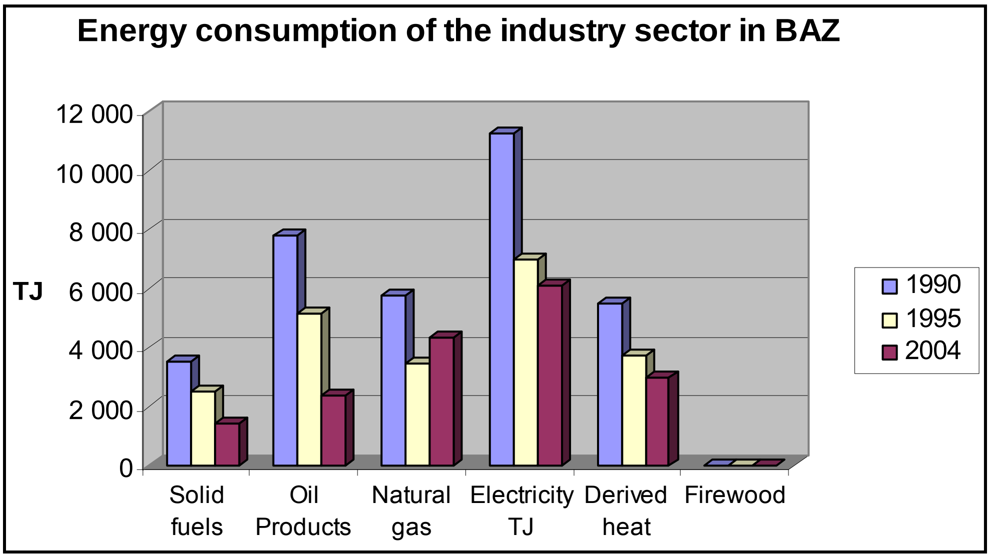


Figure 58: Development of the industrial energy consumption structure in county BAZ

From Figure 58 it can be observed that there is no industrial firewood utilization shown. The reason is that the own uses do not appear in the national energy balance as primary wood for energetic purpose. Industries related to wood production or processes however are using their firewood waste [Marosvölgyi,2005a], but without appearing in the market, therefore there is no official statistic in this regard, neither at Hungarian, nor at county level.

Besides the industrial final energy consumption which was described above, a number of fuels may be used for non-energy purposes, e.g. as raw materials for the manufacture of non-fuel products (feedstock use), for their physical properties or for their solvent properties. The petrochemical industry represents, by far, the most important user of fuels for non-energy purposes. It converts fossil fuels (oil, natural gas and coke-oven byproducts) and biomass carbon to synthetic organic products [Mandil,2004]. Based on this, the country-level statistical data about the non-energy use of fuels was transferred to county level with the simplification that only chemical raw materials were considered and estimated from the country balances with the VA-share of chemical industry between BAZ and Hungary. This simplification can be accepted, as chemical industry makes up the 70-90% of the total non energetic consumption at country level [EK,2006a]. It is important to emphasize, that due to the estimation method, important deviation can occur in the results, however, no better solution could be found. Therefore this result data must be regarded as informative.

4.8.2.4. Energy consumption of the transport sector

Statistics about transport energy consumption at county level are not available in Hungary [EK,2006a]. The reason is that even though vehicles are registered in communities, their fuel is supplied from any place. Despite this, consumption of Borsod was estimated using country level consumption and various ratios. Differentiation on road transport was given by the number of vehicles, whilst for rail transport the length of railways was used. These two sectors have significant energy consumption; 95% of the total is coming from road and 5% from railway transport with a total sum of 8,000 TJ. The fuel use of water transport was neglected because of its low share; similarly, the relevance of air transport was also not considered, as no important airports can be found within Borsod The transport sector uses mainly oil products energy sources, but electricity (for railways), natural gas and solid fuels are also consumed to some degree. However, natural gas and solid fuels are not represented in Figure 59 due to their very little amount. Time-series statistical data on national and county vehicle stock as well as on railway lengths could be derived from various sources, such as KSH [KSH,2005a], [KSH,2004b], Eurostat and OECD statistics, database of the Hungarian Investment and Trade Development Agency (ITD) and the official homepage of Borsod County (www.baz.hu).

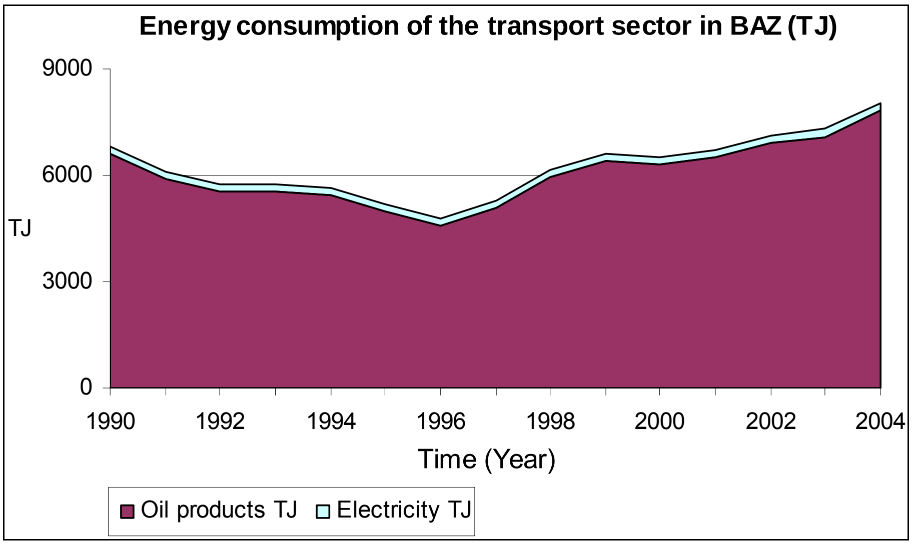


Figure 59: Dynamic changes in energy use of the transport sector in BAZ

4.8.2.5. Energy consumption of the trade and services sector

The sector of trade and services comprises several activities belonging to different NACE classes. Because of lack of statistics at this spatial level, average VA-share of each trade and service sub-sectors between BAZ and Hungary have been applied with some modifications. Since differences are not considered, the calculated time-series must be considered as informative results (see Figure 60).

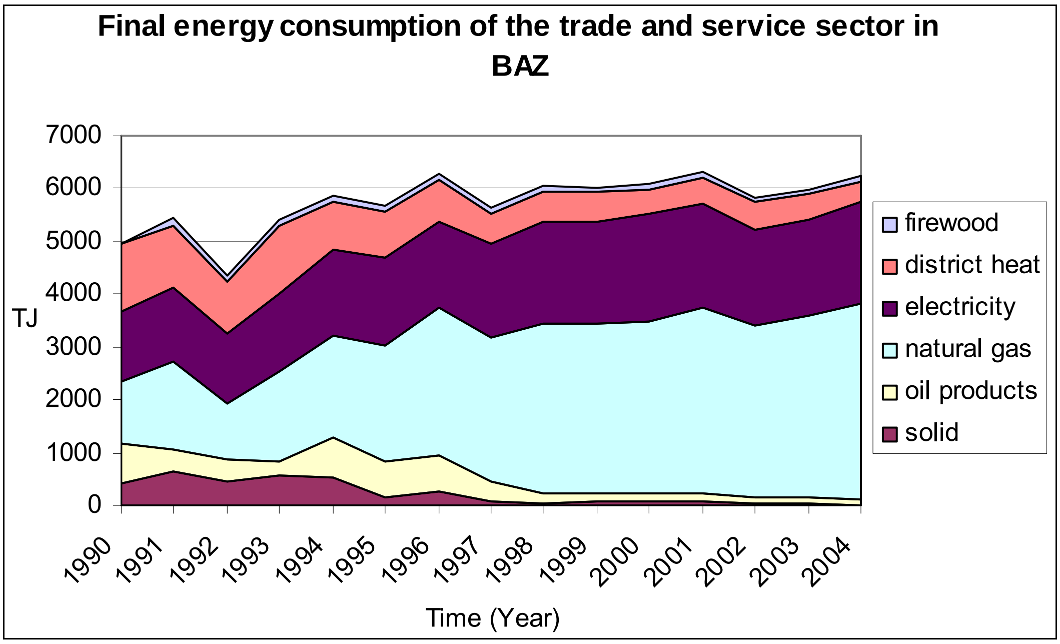
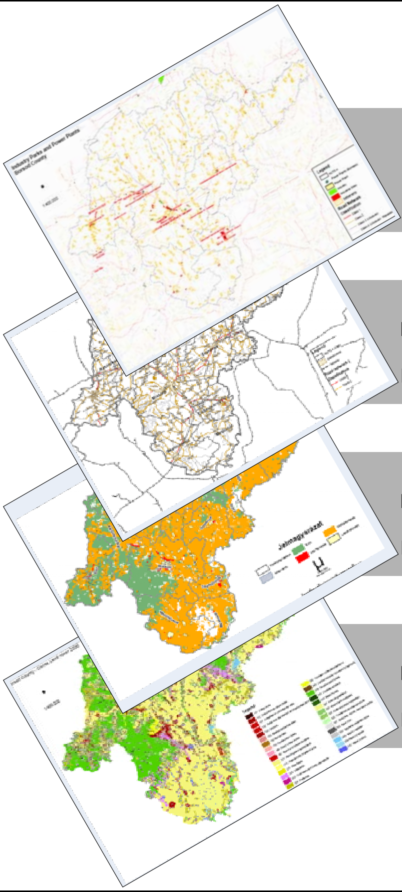


Figure 60: Dynamic changes in energy use of the trade and services sector in BAZ

The spatial distribution of the production and consumption have been prepared using Geographical Information System (GIS) software and satellite images [EEA,2000], main steps of which are displayed in

Figure 61. As result, several thematic layers were generated with the help of a GIS specialist (Lajos Dobrosi). An example is given in Figure 62, and further ones can be seen in Annex XIII.



	Thematic layers	Methodology
Layer Map use Source Indicator	Power plants location Biomass demand establishment Territorial settlement plan, Borsod	Identification of existing power plants Scan/digitalization of needed locations
Layer Map use Source Indicator	Traffic infrastructure Transportation possibilities of biomass Corine land cover 2000 Economic transportability	Convert/scan/digitalization of traffic infrasturcture components Calculation and presentation of economic collectivilibility distance
Layer Map use Source Indicator	Agricultural byproducts	Calculate and present agricultural byproducts with regional distribution Theoretical/technical potental Areas identification with pick production
Layer Map use Source Indicator	Forestry byproducts	Calculate and present forestry byproducts with regional distribution Theoretical/technical potental Areas identification with pick production

Figure 61: Example of geographical representation of available regional information in Borsod

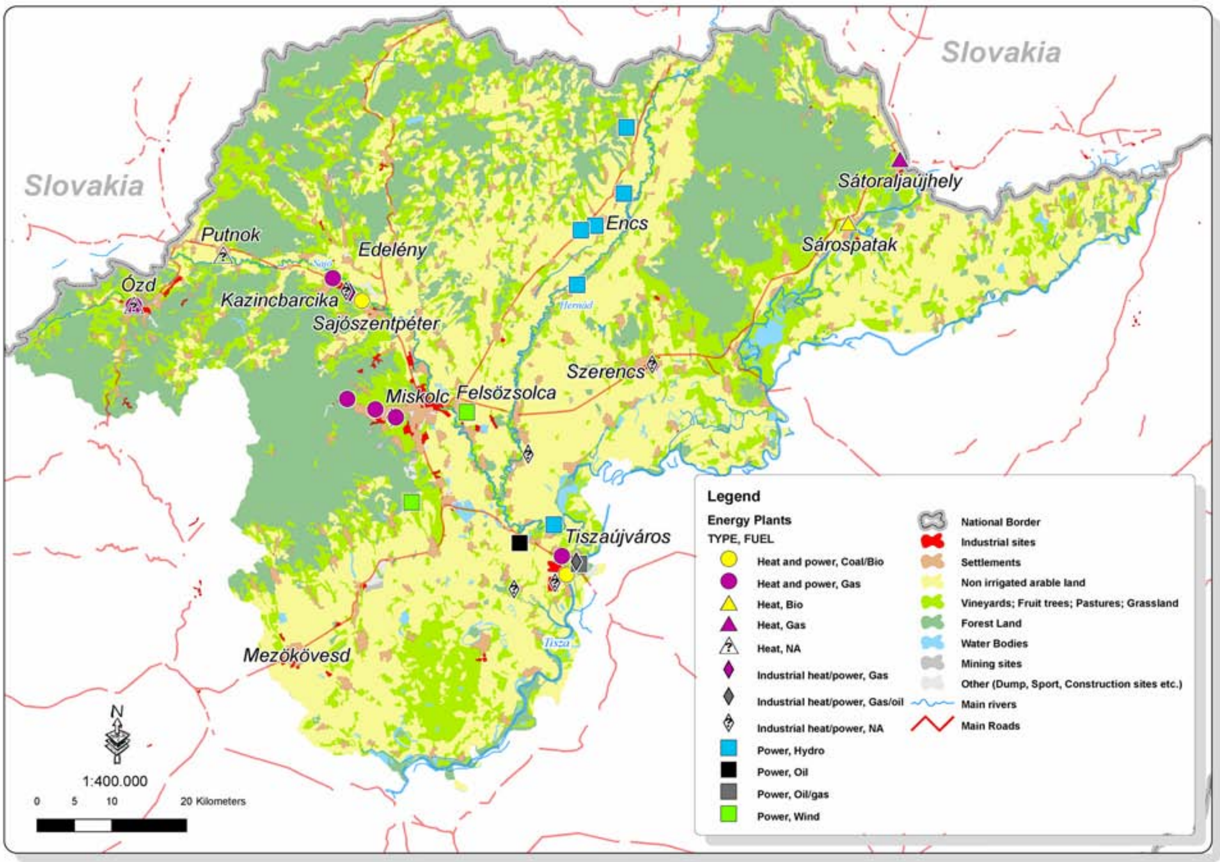


Figure 62: Spatial distribution of energy production and consumption in Borsod County

5. System analysis of Borsod County

Borsod County, representing a complex system, requires a complex analysis as well. Such analysis, following up the decision making theory introduced in Chapter 2.3 includes the identification of relevant stakeholders, formulation of problems, determination of SWOT analysis and objectives, and derivation of key indicators. Establishment and results of those are described hereafter.

5.1. Stakeholders of BAZ County

Involvement of stakeholders and possible users of the here defined tool-set is required, as it was introduced in Chapter 5.1. However, due to the limits (temporal and economic) of the current study, most of the stakeholders represent sources of relevant information, classifying them as key stakeholders (involved in the reference area, participating and collaborating actively or passively in the problems, objectives and scenario formulation) and secondary stakeholders (not directly involved in the research process; they are mainly providing data and "soft" information). The identified and involved stakeholders are listed in Table 16.

Table 16: Examples of stakeholders involved in current research

Group	Name	Function and role
Key stakeholders	North-Hungarian Regional Development Agency (NORDA)	Medium and long-term objectives of Borsod county [NORDA,2005], [NORDA,2006]
	AES Borsod power plant	Personal communication and information/data supply about the future application of renewables and power plant production in Borsod
	North Hungarian Environmental Protection, Nature Preservation and Water Inspectorate	Documentation of the plan of first straw-fired plant in Hungary
	University of Miskolc	Sustainability measurements in Borsod [Tóth,2005a], Regional development concept of Borsod [ME,1999b]
	Ecological Institute	Environmental program of Borsod [ÖI,1999]
	Agrarian Information Center	Agrarian strategy of Borsod [Fehér,2006]
	North Hungarian Forest Share Holding Company (Èszakerdő)	Ecological conflicts in county Borsod [D.Nagy,2005]
	Hungarian Electronic Association (MVM)	Historical and future planned power generation
	State Forest Service (ÀESZ)	Plantation and logging plans of Borsod's county
	Center of Agricultural Sciences, University of Debrecen (Attila Bai)	Several information, data and expert support in numerous fields
	Károly Róbert College, Gyöngyös	Perspectives and objectives of Borsod, Innovation Cluster Center in the field of biomass use
	Local government of Miskolc	Personal discussion and information support about the regional development plans in BAZ
Secondary stakeholders	KSH	Various statistical data since 1990 and forecasts, as well as methodological support
	Energy Centre (EK)	Sector historical energy consumption in details and future trends
	Eurostat	General and regional statistics
	Ministry of Argiculture and Rural Development (FVM)	Forest and agricultural inventory and regulations
	Experts of the Hungarian Energy Office (MEH)	Personal communication relating the methods applied for future energy consumption estimation
	Medium on Internet for Agrarinformatics in Hungary (MIAU)	Production and economic values from the agriculture
	Egererdő (Jung László)	Support by the forestry sector through personal discussions
	University of Miskolc (Beáta Szilasi)	Mining-related objectives and data
	North-Hungarian Environmental, Nature protection and Water Inspectorate	Detailed air pollution and legislative information as well as personal discussions
	European Commission	Databases and strategies

5.2. Analysis of regional problems

After analyzing the overall situation of Borsod and identifying the involved local players, the next step is the implicit recognition of a current undesirable situation, called problem analysis. Problems at a regional level have been identified considering to the following aspects:

- main components of sustainable development (economic, social and environmental) [EC,2005f], [EC,2006d],
- production sectors (agricultural, industrial, services related),
- spatial level (national, specific regional or local),
- energy-specific dimension (plants, communal level, demand side, supply side) [EC,2005d],
- time scale (long term, medium or short term),
- macro (national economy) or micro (enterprises) level [NORDA,2005],
- policy (environmental, energy political, employment policy, etc.) [EK,2005], [Stumphauser,2001].

The problems identified are presented in Table 17 and structured according to the main pillars of sustainable development. Detailed problems have been identified based on the detailed regional analysis. Through highlighting general regional problems, it can also contribute to identify barriers and constraints that impede progress towards sustainable development.

Table 17: Problems structured in Borsod County

Low level of economic competitiveness and regional sustainability				
Regional economic difficulties	**Regional environmental conflicts**	**Regional social problems**	**Land use, Forest and Agriculture**	**Energy**
▪ Low national and foreign investment rates (11% and 8%, respectively) ▪ Unemployment rate in the region is higher (9-10%) than the national average ▪ The income and per capita GDP is the lowest national-wide level ▪ The region is one of the least developed regions of the European Union with low value added ▪ There are few large companies having a strong market position and considerable capital The SMEs lack capital and struggle with regular liquidity problems, their market positions and competitiveness are weak, and show little willingness to cooperate	▪ Low soil organic matter in several fields ▪ Surface and groundwater pollution ▪ Large contaminated industrial areas left after the factories of heavy industries ▪ High level of carbon-dioxide pollution resulting mostly from the transport sector and energy production	▪ The number of rural population has continually been sinking over the last two and half decades ▪ The population of the region and that of the more backward small regions is continuously aging ▪ Numerous anachronistic workplaces ▪ The health of the population is poor, there are many inactive people and the mortality rate is higher than the national and European average. ▪ Few number of jobs with higher qualifications ▪ Few rural development programs The relations between R&D organizations and enterprises are insufficient.	LAND USE ▪ Low share of energy plantations ▪ High share of low quality agricultural areas ▪ Low quality traffic infrastructure FOREST ▪ Not exploited potential of forestry sector AGRICULTURE ▪ Overproduction of certain traditional crops ▪ Low diversification of agricultural products The traditional agricultural production (wheat and maize) in a significant part of the fields can be considered as no more rentable	▪ Low share of renewable energy sources ▪ High level of dependency on import fuels ▪ There is no energy concept on a county level ▪ The monopole situation of energy suppliers: centralization instead of decentralization ▪ Irrational energy consumption in the mobility, agriculture and communal sectors ▪ Low energy efficiency: high amount of energy is used for a unit production ▪ Outworn district heat system of the cities ▪ Exhausting local natural fossil sources ▪ Minimum level of experience and ambition to increase the energy efficiency ▪ Innovation and consulting with low degree ▪ Low level technologies

5.3. SWOT analysis of the energy sector in Borsod

The defined regional problems must be limited to energy-related specifications, in order to define objectives. Therefore representative information has been reviewed with active or passive participation of identified stakeholders. As results, resources or capacities (strengths), limitations, faults or defects (weaknesses), favorable situations (opportunities) and unfavorable situations (threats) of Borsod's energy sector have been defined. This method, as introduced before in Chapter 2.3.1.1 is called SWOT analysis [ÖI,1999] and its result is presented in Table 18.

Table 18: SWOT analysis of the energy sector and related components in Borsod (Source: [ÖI,1999])

Strength (S)	**Weakness (W)**
Significant energy production capacity	There is no energy concept on a county level
Experience and know how of energy production	Irrational energy consumption in the mobility, agriculture and communal sectors
Remarkable investments for the mitigation of the negative environmental impacts of the plants	High level of dependency on import fossil fuels
Establishment of the Innovation Cluster Centre, with a main goal of clamping the biomass related R&D, services, production and other activities	Low energy efficiency in the energy production sector: high amount of fuel is used for a unit energy production
Significant amount of byproducts both in agriculture and forestry, representing biomass	Environmental pollution of the plants determine the air and water quality locally
	Exhaustion local natural fossil sources
	Increasing demand for energy in all sectors
	Minimum level of experience and ambition to increase the energy efficiency
	The old plants with low efficiency and high environmental pollution will be closed up in 2012 and 2013
	Still almost monopolist situation of energy producers
Opportunities (O)	**Threats (T)**
Structural change and development in the agriculture	The county can be in a vulnerable energy supply situation due to high level of energy/fuel import
Exploration and exploitation of local alternative and renewable energy sources in a county level	Increase of the environmental negative impacts resulting from the energy production
Increase of energy efficiency in various sectors	Revive of the energy-demanding sectors
Modernization of energy production and transformation technologies, decrease the environmental pollution	Straining of exploitation of low quality fuels with high emissions
Decrease the dependency of the county on the imported fuels	

Resulting components of SWOT can be combined and used for the formulation of possible future strategies. Under these conditions, the internal factors (S and W) can be manageable, which means that advantages or disadvantages in the region can be exploited and used or avoided/bettered. On the other hand O and T should be considered as external appraisal, therefore not being able to influence significantly. Combining the positive factors for example (S and O) future alternatives can be formulated, selected examples of which are shown in Figure 63.

Regional and problem analysis as well as SWOT contributes identifying regional vision and objectives, which are introduced in the next section.

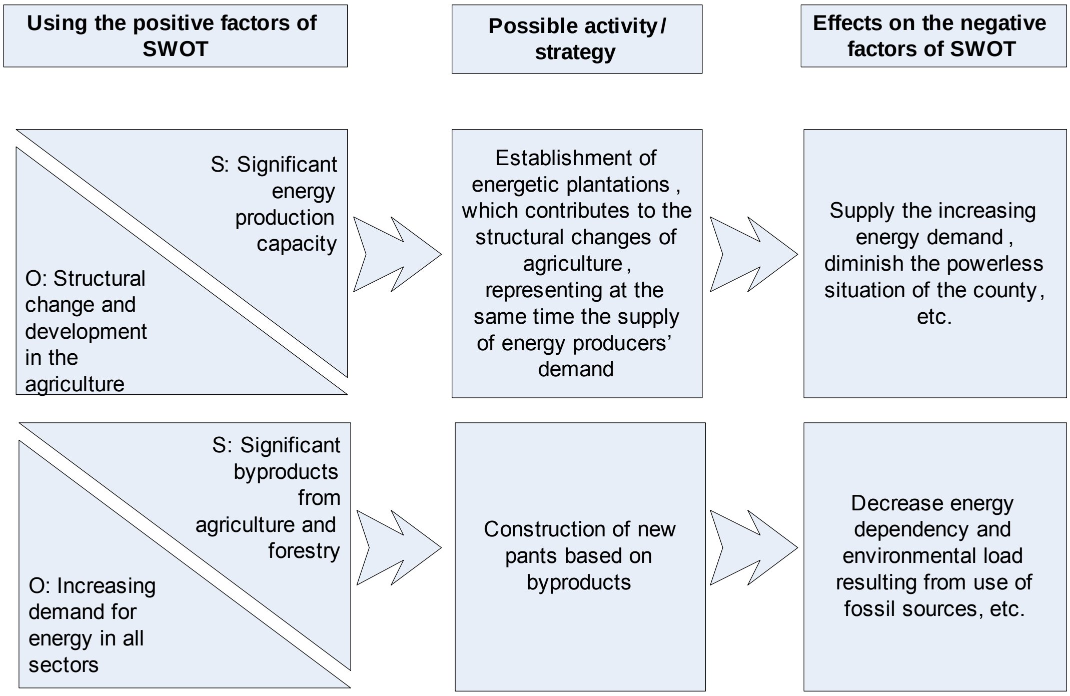


Figure 63: Identification of possible future regional options based on the SWOT results

5.4. Vision and objectives of Borsod County

A regional vision can be defined as the desired future situation formulated with one sentence; the picture as the region would like to see itself in the future [OSEC,1988], [Wolfbauer,2005]. The vision of Borsod can be given as the following: 'An economically liable and socially stable county, where the use of renewable energy sources contributes to economic development whilst enhancing environmental protection and appropriate land use, and debates the dependence on import energy sources, giving also new jobs for especially rural workers with low education, retaining in this manner the local population' [Tóth,2005a].

This vision can also be captured as a short and brief version of the structured and detailed objectives. Objectives are on one hand the positive reformulation of problems, on the other hand factors to be enhanced or developed. Some possible ways for objectives' representation are LFA, AHP and ANP, among others, as introduced in Chapter 2.3. Whilst AHP is appropriate for a hierarchical structuring, ANP captures a network system with feedbacks and internal loops. Construction of both systems requires a combination of a top-down (TD) and a bottom-up (BU) concepts.

First the overall goal must be formulated, comprehending the European, national and regional/local objectives as well. The goal set within this study is to increase regional sustainability and competitiveness through biomass utilization. This overall goal is then defined in more tangible ones (Level 1 objectives), namely economic, social and environmental enhancement, representing the three primary dimensions of sustainable development [Kellly K.L.,1998] [EC,2001a]. Level 2 of the system defines the Level 1 objectives in more operational terms, derived from the upper level objectives (TD), but also taking into consideration the specific regional ones (BU) [Dyner,2005]. Level 3 contains derived sector indicators [Quaddus,2004], [EC,2005d], [Madlener,2000] ('I' preposition in the name refers to an indicator). The resulted objective system is presented in Figure 64.

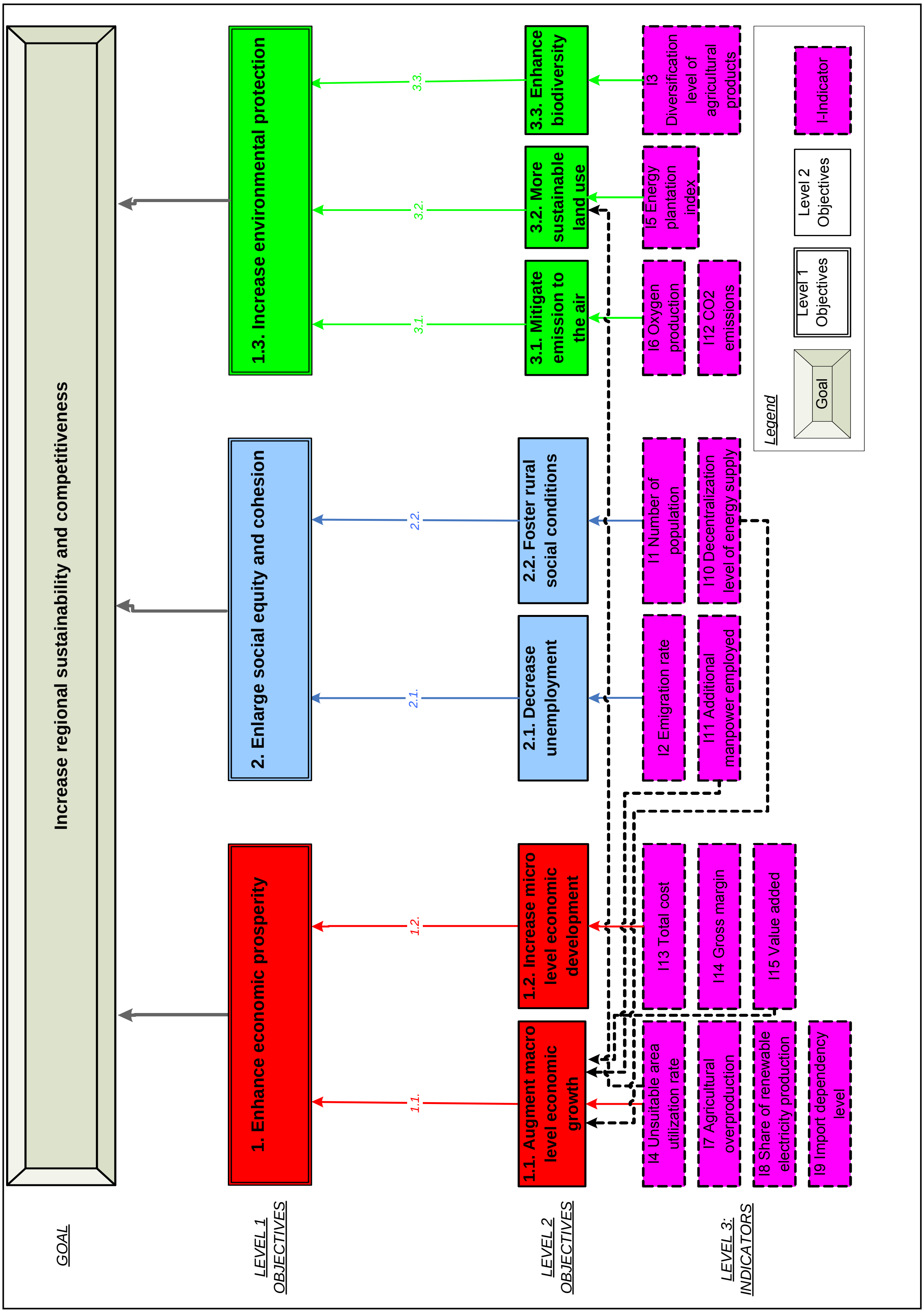


Figure 64: Structure of the Borsod County’s objective system

Table 19: Objectives of the objective tree of Borsod with their descriptions [EC,2004], [EC,2001], [EC,2005c], [EC,2005b], [EC,2006], [EC,2005a], [UN,2007], [WED,2000], [Madlener,2000], [NORDA,2005]

ID	Name	Definition
	PROMOTE REGIONAL SUSTAINABILITY AND COMPETITIVENESS THROUGH USE OF BIOMASS FOR ENERGETIC PURPOSE	Includes the set national and European goal since 1992, as well as summarizes the regional objectives. Borsod County represents a great potential of biomass resources, therefore their production and use is desirable. The use of which must be performed in a manner which contributes to economic development and improvement of the social situation and environmental compartments
1	**Enhance economic prosperity**	Promote a prosperous, innovative, knowledge-rich, competitive and eco-efficient economy, which provides high living standards and full, and high-quality employment. The improvement of economic competitiveness should take place in both macro and micro levels.
1.1.	**Augment macro level economic growth**	Contribute to the maintenance and increase of economic competitiveness of the country. Objectives usually are specified for a region but suit to goals defined at European and national levels.
1.2.	**Increase micro level economic development**	Represents the level of production in the energy field, people and enterprises involved in biomass production/energetic plants establishment, collection, transportation and conversion. It must be noted that the BtE chain is considered as one unit. That means that there are no intermediate transactions (selling) between the point of biomass production and energy generation.
2	**Enlarge social equity and cohesion**	Promote/improve social competitiveness, creating equal opportunities and improving quality of life in general.
2.1.	Decrease unemployment	Unemployment is the condition and extent of joblessness within an economy. Decreasing unemployment contribute both to economic and social enhancement, through establishing new workplaces and retaining the emigration.
2.2.	Foster rural social conditions	Social rural conditions refer to the general social circumstances within the region, expressed by the number of population or other more specific parameters referring to the energy sector.
3	**Increase environmental protection**	Safeguard the earth's capacity to support life in its diversity, respect the limits of natural resources and ensure a high level of protection and improvement of the quality of the environment. Prevent and reduce environmental pollution and promote sustainable consumption and production to break the link between economic growth and environmental degradation.
3.1.	Mitigate emission to the air	Applying new alternatives of energy generation from biomass, which contribute to less atmospheric pollutant emissions, with special focus on greenhouse gases, such as CO2.
3.2.	More sustainable land use	Altering unsustainable land use patterns which effects negatively the land's components: physical space and the surface topography, as well as the associated natural resources of soil, mineral deposits, water, and plant and animal communities.
3.3.	Enhance biodiversity	Preserve biodiversity and function of natural areas. Could be achieved by controlled wood harvesting intensity or agricultural production.

5.5. Indicators of regional sustainable development

In the process of breaking down objectives into more specific ones, the last step is to derive the bottom-most level, where the indicators take place. Indicators contribute to an objective assessment of performance by describing objectives in measurable 'empirically observable' terms. As described in Chapter 2.3.1, this is a very important step, since indicators stand for the represented objectives and for possible alternatives. Therefore an appropriate number of representative indicators must be included [Tesch,2003]. Based on the basic sustainability issues represented previously, as well as on the regional objectives, the indicators included in Table 20 are proposed as a measure for increasing sustainability in Borsod. Annex XIV. summarizes the indicators presented with their name, unit of measurement and short description, ass well as utility functions (see net Chapter). As options for future application, other indicators and components could be included, such as the development of know-how and technologies, involvement and therefore development of SMEs from various sectors (transportation, agriculture, etc.) support regional planning through data collection, etc.

Table 20: Identified indicators of for measurement of sustainable development in Borsod

ID	Name	Unit of measurement
I1	Number of population	Person
I2	Emigration rate	%
I3	Diversification level of agricultural products	Dmnl
I4	(Agro-) unsuitable area utilization rate	Dmnl
I5	Energy plantation index	Dmnl
I6	Oxygen production	1000 t
I7	Agricultural surplus production (overproduction)	t
I8	Share of renewable electricity production	%
I9	(Energy) import dependency level	%
I10	Decentralization level of energy supply	Dmnl
I11	Employment opportunities	Person
I12	Unit CO2 emission	kg/TJ
I13	Unit total cost	EUR/TJ
I14	Unit gross margin	EUR/TJ
I15	Value added	EUR

Comment: %-percentage, Eur-Euro, TJ-Terra Joule, Dmnl-Dimensionless, t-ton, ha-hectare

5.5.1. Calibrating indicators

Indicators of the established structure must be calibrated, which is, as described in Chapter 2.3, their normalization against subjective utility functions. Figure 65 gives an example, where the calibration of '(Agro-) unsuitable area utilization rate' is given. In the abscissa the absolute (measured/calculated) values of the indicators are positioned with its unit of measurement. In this example, it is the rate at which agricultural areas with not suitable conditions are utilized. Since unsuitable areas sum up 47% of the total agricultural areas, this is the value where indicator reaches its maximum utility (10). Because of current level (47% unutilized areas) are taken, this is minimum level which should be improved, representing therefore the minimum utility (1). To overcome this situation, significant changes must be made in the agriculture and other related sectors, which require huge effort. Therefore, at the beginning minor increase in the indicator represents a relatively high increment. Later, applying Gossen's First Law, the marginal utility is diminishing until it reaches the maximum possible value. The calibration functions of further indicators are presented in Annex XIV.

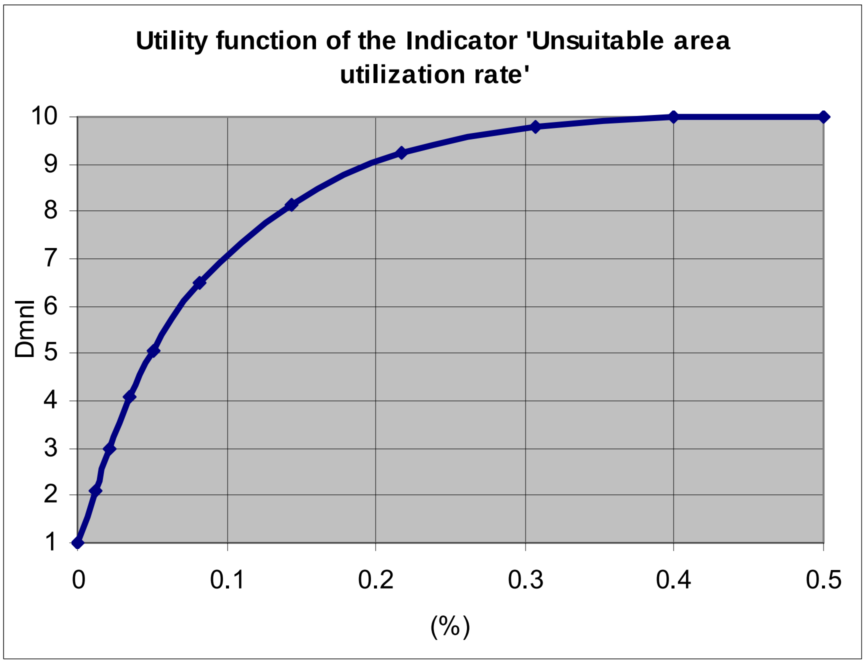


Figure 65: Example of indicator calibration

5.5.2. Scales of measurement (weights)

Once the structure is built, its components must be compared to derive their relative weights (see Chapter 2.3) through comparing them in pairs, thus making the correspondence indirect [Saaty,2005]. Via weighting and synthesizing the different levels, AHP provides an appropriate solution as perceived by the decision makers. It is noted that although AHP does not optimize, it does provide ‘‘satisfactory’’ solutions [Quaddus,2004]. The fundamental scale of AHP is of absolute numbers used to answer the basic question in all pairwise comparisons: how many times is one element more dominant than the other within a matrix, with respect to a certain criterion. According to Saaty [Saaty,2005], a scale containing nine divisions seems to be the most accurate (see Table 21). The presented scale have been applied to compare all objectives and indicators and resulting their weight within the entire tree.

Table 21: Fundamental scale of absolute numbers [Saaty,2005]

Intensity of importance scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Very morderately more	Experiment or judgement is very slightly favor one activity over another
3	Moderatly more	Experiment or judgement is slightly favor one activity over another.
4	Moderatly-strogly more	Experiment or judgement is slightly-strongly favor one activity over another.
5	Strongly more	Experiment or judgement is strongly favor one activity over another.
6	Strongly-very strongly more	Experiment or judgement is strongly-very strongly favor one activity over another. It's dominance demonstrated in practice.
7	Very strongly more	Experiment or judgement is very strongly favor one activity over another. It's dominance demonstrated in practice.
8	Very-extremly strongly more	Experiment or judgement is very-extremly strongly favor one activity over another. It's dominance demonstrated in practice.
9	Extremly more	The evidence favouring one activity over another is of the highest possible order of affirmation.

Priorities

After setting the relative importance within the Priority Matrix (PM) (see Figure 66), the Vector of Priorities are calculated (Equation. 2). Afterwards the VoP is normalized (Equation 3) and used as final weight.

$$VoP_{xi} = POWER(c_x!;1/n) \qquad \text{Eq.2}$$

VoP_{xi}= i. Vector of Priorities; c_x=components of Matrix row; n=number of criteria

$$nVoP_x = VoP_x / \sum VoP_{xy} \qquad \text{Eq.3}$$

$nVoP_x$= Normalized VoP

Level 1 priority matrix

		1 Economic prosperity	2 Social equity and cohesion	3 Environmental protection	Weight
1	Economic prosperity	1	3	5	**0.648**
2	Social equity and cohesion	0.333	1	2	**0.230**
3	Environmental protection	0.200	0.500	1	**0.122**

Priorities

	Vector of priorities	*Normalized vector of priorities*	*Number of criteria (n)*
	2.466	*0.648*	*3*
	0.874	*0.230*	
	0.464	*0.122*	
SUM	*3.804*	*1.00*	

Figure 66: Priority matrix of Level 1 objectives

Consistency

If there are more than two components to be compared within the matrix, the consistency of the settings should be controlled. The following method has been processed for testing the consistency of matrices within this work [Saaty,1980]:

1. Defining the sum of columns of PM

$$\sum PM_y = \sum c_{y_i} \qquad \text{Eq.4}$$

2. Calculating χ_{max}: multiply the columns of matrix and the normalized vectors respectively

$$\chi_{\max} = VoP_{xyn} * \sum PM_y \qquad \text{Eq.5}$$

3. Computation of the Consistency Index (CI)

$$CI = (\chi_{\max} - n)/(n-1) \qquad \text{Eq.6}$$

4. Computation of the Consistency Ratio (CR) where RCI is chosen from Table 22. A CR of 0.10 or less is considered acceptable

$$CR = CI / CRI \qquad \text{Eq.7}$$

Table 22: RCI values according to the number of criteria (n) within consistency in AHP

n	3	4	5	6	7	8	9	>9
RCI	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Figure 67 shows an example, the result of consistency testing for level 1 objectives. The weights defined for further objectives within the system can be viewed in Annex XV.

Sum of columns of priority Matrix	Resulting from 1., 2. and 3.	1.533	4.5	8
c max (Delta (AxB))	Multiply the columns of matrix and the normalized vectors respectively	3.004		
Consistency index (CI)	(c max-n) / (n-1)	0.002		
RCI	Taken from the table	0.580		
Consistency ratio (CR)	CI/RCI	0.003		
Status	CR of 0.10 or less is considered acceptable	Accepted		

Figure 67: Consistency result for Level 1 objectives

Since several absolute values of indicators are coming from the dynamic modeling, to be able to apply the introduced system in the future, the model itself must be built, calibrated and simulated. As results, indicator values of current year can be derived, as well as from the future until 2020, in all scenarios cases. Indicator values can than be built into the objective tree with their scores, which allows running the system and deriving values of sustainability achievements for selected years. Quantitative changes can serve as basis for evaluating biomass alternatives. Regional biomass scenarios in Borsod are described in the next chapter.

5.6. Empirical scenarios of development the energy sector

Scenario building is one of the most important instruments of long-term economic and regional planning. Using the model and the initial data a number of scenarios covering the 2004 to 2020 time span have been developed, aiming at (1) checking the consistency of a number of assumptions about evolutions by integrating them into one model, (2) formulating a set of visions about the future, (3) identifying data needed for the more quantitative policy model, and (4) getting a first exploration of possible (meta-)policy options [Tesch,2003]. For a region, an infinite number of development scenarios can be outlined and described. To select scenarios within this study, they must share some particular features, as described below:

1. Their creation must be based on energy concepts, relationships and theories. It was, however, unavoidable to touch upon political, social and other issues of development as well, but the fundamental factors analyses and prognosticated are of energy production.
2. The scenarios are arranged along two axes, which represent the energy process (production, extraction, transport and conversion) of various energy forms, and on the other hand the economic social and environmental effects and consequences of them. These axes serve as the principal factors of the scenarios (Figure 68).

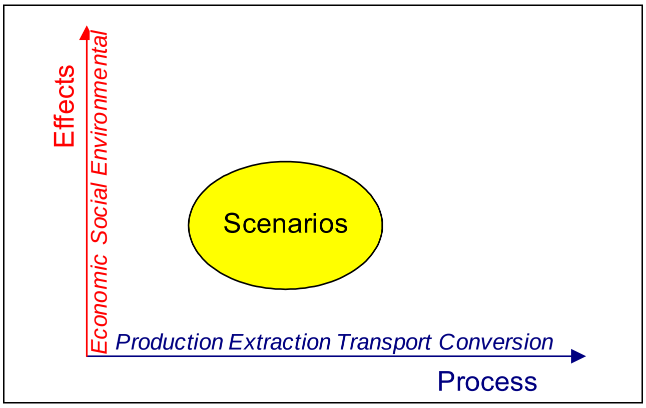


Figure 68: Positioning of scenarios within the two main axes

The Process axis describes the principal steps of processing energy from biomass, namely the production, extraction, transportation and conversion. This can then be applied for each scenario, producing and extracting fuels (both renewable and fossil), transporting them and using in plants. The whole process is described in details in the following chapter. **The Effects** axis represents the possible effects resulting when applying the process steps. The effects are categorized according to the sustainable development principles, such as economic, social and environmental.

Realistic scenarios covering the 2005 to 2020 time span can be developed in various ways of using biomass for energetic purpose. All possible chains within Borsod have been summarized and presented in Figure 69. From the presented figure, the colored pathway is to be proven more probably, after the results of the theoretical potential analysis and the assessing of the regional plans and objectives, taken into consideration the existence of technology and management, more available variety of plantations, etc. [Bai,2002]. Final selected scenarios are therefore based on real regional objectives and plans, potentials and limitations. However, it must be stated, that scenarios are not the full adaptation of regional projects, but incorporate their basic concept, objectives and data. But, since they are based on various different information and data sources, results cannot be viewed completely as effects of real and existing plans. Relevant scenarios are detailed hereon and more information can be found in Annex XVI.

5.6.1. Business as usual (BAU)

The scenario BAU supposes the development of social, economic and environmental components as in the long- or medium-term in the past; introduced in details by each sub-model. This does not mean that the whole system will run just as before or will keep the same figures as at the last given year; it means that the system sets the components to behave according to the best available know-how about the future. That includes the involvement of known technological changes, existing or planned political, regulative and legislative issues. Besides, the future run of the **population** is based on existing forecasts in county level [NÈPINFO,2006], which is to be declined due to persistent emigration. The increment, logging and other changes of the future **forest** sector are given by using past historical data series as well as forest plans. Accordingly, the forest area is being increased in coming years. The future sectoral **land cover** shows is defined according to past changes, which consist of descending water bodies, slightly descending agricultural surfaces and ascendant artificial and forest areas. The **agricultural** production follows the historical patterns of the share and amount of crop production and residues. The exploitation of fossil primary **fuels** ended in 2004, and no new opening of mines is planned in the future. The **energy production** based on renewables persists on the existing installed capacity in the county, with 5.5 MW hydro, 2 MW wind and 79 MW biomass use. The electricity and heat production will not have structural changes in the future. Existing plants will run according to their capacity plans; two of them will close in 2012 and 2013. Total energy production is about 45,000 TJ yearly. The **consumption** of various sectors are given separately, for agriculture, industry, households, transport, trade, services and the energy sectors, based on existing prognoses, estimations and trend lines, using data set from the short or medium term in the past were applied. Summarizing, the use of coal and oil will decrease, and the gas will continue to be used in a greater amount.

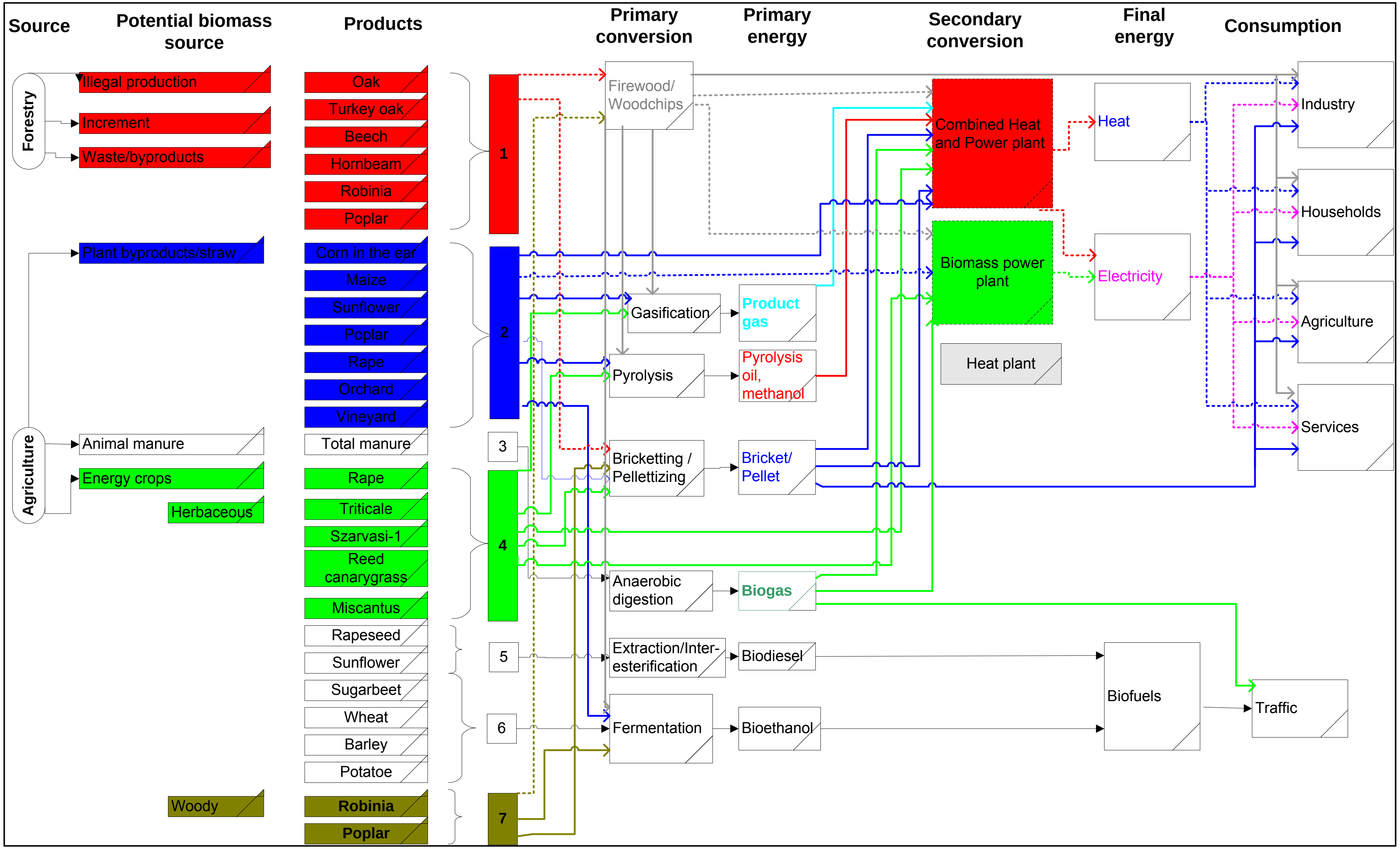


Figure 69: Theoretical development paths of scenarios

5.6.2. Boiler retrofit to biomass (Retrofit)

The denomination of this scenario refers to the retrofit of an existing plant's boiler in the Borsod plant in Kazincbarcika in year 2008, where already has been a fuel switch in 2002 (from coal to biomass). The primary reason of the switch is the legal pressure to decrease environmental pollution of the power plant. Secondarily, the share of electricity produced from renewables has to increase in Hungary and the underwriting prices and other supports facilitate their use. The increased demand of renewable fuel will require its further supply.

Information and data resulting from related studies have been analyzed and implemented for the built of the Retrofit scenario of this work. Most information were taken from specific assessments from the existing retrofit plan, but other literature and statistics were also used. Therefore the scenario is not the adaptation of the existing fuel switch plan, but a combination of its characteristics with other information. The retrofit within this study is planned with 30 MW_{el} capacity and about 220 GWh green electricity production yearly. When considering the selection of fuel, it was determining that the forestation level is high in the area (24% in comparison with 19 % country average) and expected to increase, whilst there is still a potential of not collected **residues**. The solution could therefore be represented by the statement of the project 'Current role and future possibilities in the rural development through biomass use for energetic purpose' (FKFP 0069/2001): In North-Hungary the utilization of exploitable forest biomass and byproducts for heat, power generation, and export is to be proposed. That is also defined by related local energetic plans [KK,2003], which was then adopted into semi-hypothetical Retrofit scenario. The costs, environmental pollutions and social impacts of a possible retrofit plan was calculated within this study based on available information and several data sources.

As availability of residues and byproducts are limited and might not be sufficient for the retrofit at current forest growth and firewood demand, the establishment of **energetic woody plantations** is planned within this scenario. Such plantations support sufficiently the demand, having only 4 years cutting cycle (in comparison with those of energy forests with 20-25 years). On the other hand such short rotation coppice (SRC) energetic woody plantations can be established in agricultural areas without changing their legal land cultivation class [Marosvölgyi,2007]. According to Austrian [Konrad,2004] and Hungarian [Marosvölgyi,2000] studies, energy plantation can be accomplished in all agricultural areas which are not needed to supply human alimentation demand (Eq. 8.)

$$ES = AA - DSS \qquad \text{Eq. 8}$$

ES=Energy Surface; AA=Agricultural Area; DSS=Demand of area for self-sustaining alimentation

Within this overall limit, energy plantations are expected to be established at areas with conditions of arable farming, so in areas where agricultural production has or might have taken place, but there is a lack of the demand for the crop (surplus production), or the security level of production is low (inundation, flood), therefore woody plantations could be established [Bai,2002]. According to the natural makings of Borsod and the high shares of low quality land, poplar has been identified as possible plantations by local studies. Successful research is going on in the West-Hungarian University in Sopron (Prof. Marosvölgyi) about the poplar and its features. The plantation area within current model will be realized in the mentioned unsuitable arable areas with low productivity conditions; wheat and maize have been assumed to be displaced, as avoiding their overproduction is an important objective concerning regional development. Establishment and run of plantations must be economic, which can be achieved considering following conditions [FÖK,2006], [Bai,2002], [EC,2004d]:

- the energy producer establishes it on his own property,
- possibly few participants of the whole chain, avoiding intermediate sellings,
- the possibilities of the utilization (farm-management, authorities, etc.) are given
- existing and supporting policy
- the product has been entered into a long-term contract or it is part of an energetic association

Therefore, assuming that those conditions will be met in future investments, the followings aspects are considered when setting Retrofit scenario:

- establishment of plantations will be realized in own fields (no costs of buying or renting areas)
- rapid growing species are planted with high density
- technology is available, representing a transition between agriculture and forestry, but their rent is needed
- no intermediate selling during the whole biomass chain, thus the project investor is aiming all fuel production, transportation and energy generation (Manpower and material costs are taken into consideration)
- yearly average yields are realized and figures at a scale less than one year (e.g. monthly production) are not represented in the model. However it can be concluded that it gives employment basically in the winter period, when the unemployment is the highest otherwise
- plantation of 2,000 ha in the given 'Project year' (2008) is established
- continouous plantation of 2,000 ha up to 10,000 ha yearly
- harvest after 4 years with technology rented
- after 5-6 harvest it must be replanted (out of the simulation range) [Bai,2006]

Parameters of its plantations, collection and use are represented in the Process sub-model (Chapter 6.4.6 and 6.5.8), including the considered costs, manpower needed and CO_2 pollution, among others.

5.6.3. Straw-fired plant (Straw)

The slightly increased demand of electricity in the city of Miskolc, as well as the run off of existing power plants in the region promoted the formulation and application of a new straw-fired plant. Studies about its parameters and impacts can be found for Miskolc and Szerencs city [ETV,2006]. The information available on those plans have been used to build the Straw scenario. According to that a 49.91 MW_{el} capacity plant is supposed to be established in the year 2008 on 2.6 ha with two steam boilers. The primary feedstock of the boilers of 32 % efficiency will be Hesston straw bales, collected from 80,000 ha surrounding agricultural field. The plant will secondarily use sunflower and corn stalk, firewood and wood chips with 15-30% moisture content during its life span, 25 years. Costs, operation hours, quantitative fuel demand, social effects and the technological parameters are included in Chapter 6.4. Straw could be used for other purposes as well, for example stubble-field firing, working of vegetal residues into soil, realization (sales), littering, paper industry, forage of cultivational byproducts, allocation of organic fertilizer into soil, etc. [Bai,2002]. But such a comparative analysis (comparing various uses of fuels) is not the objective of the study, as those are not predefined as future alternatives in Borsod. Summarizing the three scenarios Table 23 gives an overview and Annex XVI describes them in more details.

Table 23: Definition of biomass scenarios applied in the BAZ regional model

Scenario name	Input variables	Description
Business as usual (BAU)	Population	Shows slightly decline according to forecasts of the Hungarian Central Statistical Office (KSH).
	Logging	It is given for the sort of forest function (protected/economic/etc.) and ownership (private/state/etc.) according to the national forest plans of 10 and 30 years.
	Forest area	In compliance with the forest law (LIV/1996), the area of forest land cannot decrease. Its calculation in the scenario is based on the initial value and the natural forest growth as well as plantations.
	Various land use categories	It is supposed that in the future no intervention for the change of the land use categories will be made, thus historical altering continue.
	Agricultural production	Production of agricultural crops and animal husbandry will have a continuous development based on their current tendency.
	Energy production	Production and closure (in years 2012 and 2013) of power plants are according to their capacity plans.
	Fuel production	Fossil fuels production ended (except lignite) which results in increasing fuel import. Firewood is further supplied from the surrounding's forests as well as imported.
	Energy consumption	Using existing forecasts of energy consumption trends or setting them by each sector and fuel type.
Retrofit	Residues use	The calculated economically collectable residues from forest will be collected to supply the power plants in BAZ.
	Various land use categories	No rentable agricultural areas (with current maize and wheat production) will be transformed into energetic plantations (SRC) with 2 years harvest frequency. The overproduction of energetic wood will be sold as fuel.
	Energy production	Fuel switch from coal to biomass with an expected 30 MW capacity in 2008, according to a local retrofit project.
Straw-fired plant (Straw)	Energy production	Building a new straw-fired power plant in 2008 in Borsod, implementing all related costs, emission and employment effects.
	Residues use	Agricultural crop residues will be collected from the surrounding fields, with all collection and transportation costs, manpower demand and CO_2 emission.

6. System dynamics modeling of Borsod

For modeling, simulating and analyzing Borsod County, especially its energy system, a system dynamics model has been built, calibrated and simulated with regional data and information. The built model is a conceptual model in the sense that it helps to understand how the systemic properties of a region, combined with a selected set of parameters reflecting policy orientations, affect the general sustainability. In other terms, the aim of the model is not to do exact predictions about the future, but rather to gain insight in the relationships between different aspects of system interest. However, most of the inputs are data; therefore assumptions can be taken as semi-hipothetical. The built multi-view model spans more than 200 variables and equations, the build, set and run of which is presented within this chapter.

6.1. Build and set the model

Figure 70 comprehends the working steps to build the regional biomass model for Borsod. First its main **purpose** has been formulated for identifying the most crucial components. That is, as described before, the representation of Borsod county and the dynamic and feedback systems of its components when applying realistic biomass scenarios.

For a successful overall application first important **concepts** and approaches were reviewed, to address the interdependence of all aspects of development, like competitiveness and sustainability (introduced in Chapter 2.). Spatial, economic, social, environmental, political and technological aspects are incorporated in such a system.

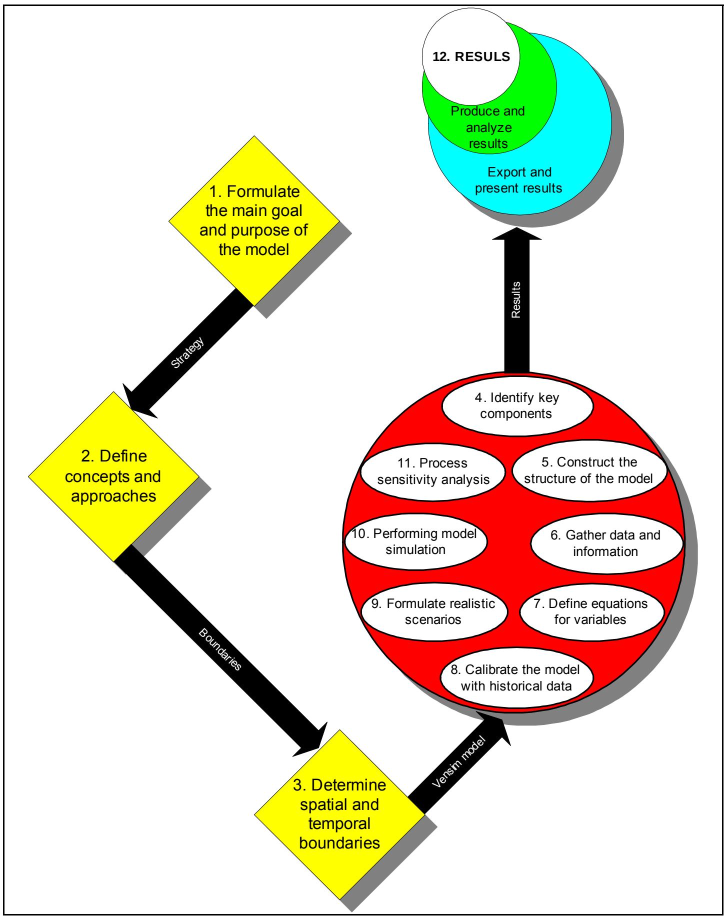


Figure 70: Activity steps for building a system dynamics model in Borsod

A set of **spatial and temporal boundaries** has been introduced in previous sections: the spatial level is Borsod County; the initial time is 1990, when historical data are given or calculated, whilst final time is the end of the period to be analyzed, year 2020, when results can still be considered as reliable. After these settings the model itself can be built, starting with the identification of key components. This is important to avoid the use of numerous variables, without relevance and to find the main focus of the model. Afterwards the construction of the model structure can be started, including the identified main components. These activities are described by the sub-models respectively.

For developing and applying the system dynamics model for Borsod with special focus on the energy sector the following steps have been carried out: (1) identification the key variables, (2) definition the reference modes, the patterns of behavior over time, (3) definition of reality check statements about the interaction of factors involved, (4) statement of a dynamic hypothesis, and finally the (5) calibration and simulation of the model with various scenarios.

When the overall structure and key variables are decided and drawn, **data** must be collected and processed in the needed unit and form according to the data management process detailed in Chapter 4.2. It must be noted that data processing follows through the whole research period, as an iterative activity: once model demand is defined, it must be controlled by data available; if data are not available or not possible to gather, the structure can slightly be changed, leaving the underline structure as set. This is also concerned vice versa: data sources, gathering and processing are modified and updated according to the development of the model. To govern the relationships for and between variables, their patterns of behavior over time are determined by **equations**. This is a complex process, including several measurement, calculations, estimations, forecasts and other methods, which are detailed by each sub-model. It is very important to emphasize, that the biggest part of calculations and estimations have been processed outside of the model, in order to keep the model as simple and transparent as possible, as well as easy to understand and handle for third user. Giving reality check statements about the interaction of factors involved is the role of the **calibration** of the model: validating the built model through comparing its behavior to historical time series data.

For the representation of the dynamic regional issues one single coherent and complex model was built within the Vensim environment. However, due to the extension of the model, the numerous variables and connections, its representation is hardly to perform in only one view. There is a path for expanding the model; through splitting them into the so called ‘sub-models’. This split whereas does not cause a functional ‘break’ in the model; only the structure is shown in parts, for the sake of a perspicuous analysis. Sub-models however are connected to each other through “shadow variables”, creating one interacting and dynamic system. The involved sub-models are detailed in Chapter 6.4 alongside with description and explanation of them.

Before detailing the model structure and sub-model features, a summary of the model’s main inputs setting and outputs resulted is given in Figure 71. In the middle of the structure stand the sub-models, comprehending into the model. All variables are defined by functions, using inputs and providing outputs. Internal interactions can be found between and within sub-models. To have an overview about the built biomass regional model, Figure 72 represents the main connections among its sub-models. Not all linkages have been omitted, to enhance the overall clarity of the structure through emphasizing the dominant behaviors. Besides, several issues and connections cannot be involved into the model, going beyond the scope of this study. The arrows indicate casual relations within the model.

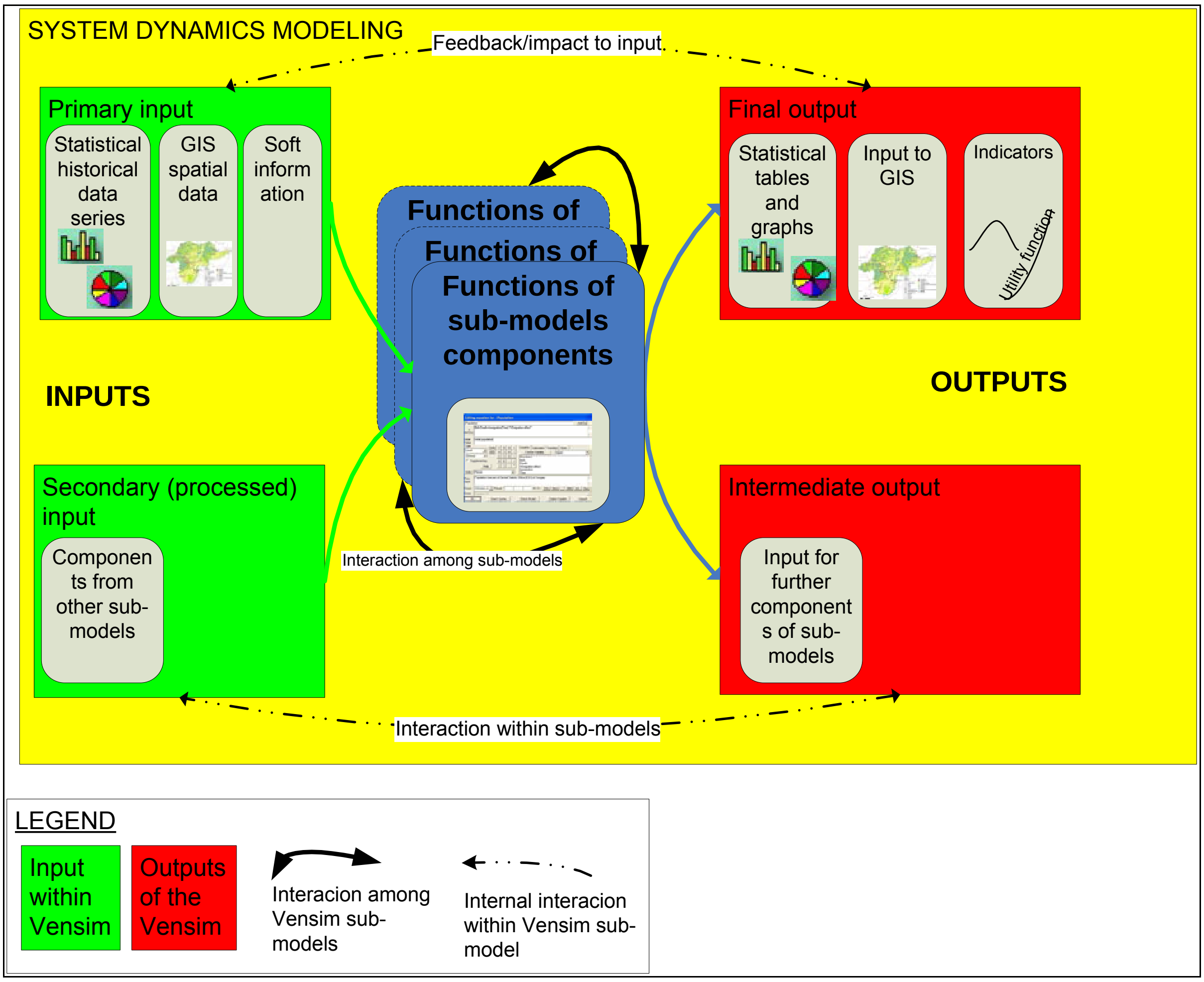


Figure 71: Main settings of the Borsod dynamic model

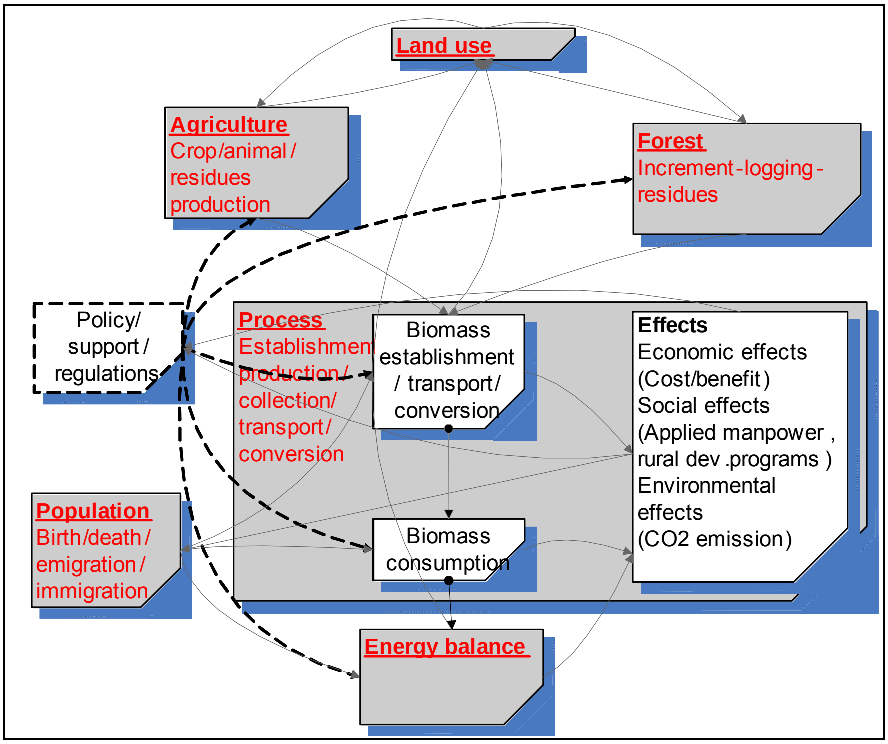


Figure 72: Overall connections within the dynamic regional biomass model of Borsod

6.2. Subscripts

Often a piece of a complex model needs to be repeated over and over again. One method is to create one structure, then copy and replicate that structure as many times as needed. However, this can lead to complex diagrams and hard-wiring of constant values and a very huge structure. A more effective way to repeat structure is to use subscripts. A subscript is created and added to the original structure. Afterwards the numbers of structures and numerical values for all structures can easily be changed. Subscripting language in this way enables construction of very advanced arrayed models. Subscripts are enclosed in square brackets directly following the variable name [Ventana Systems Inc.,2006]. Within the biomass model three subscripts were applied, namely the agricultural crops, animals and fuel types, described below.

Agricultural crops and animals

As agriculture is one important sector of biomass source, the most important crops have to be implemented into the model, with their site extension, yield and residues production. All crops have the same structure of equation, therefore to avoid the numerous similar structure, agricultural crops have been identified as subscript components, containing the most important crops within Borsod. To identify those, agricultural statistics have been analyzed and relevant crops were identified according to NACE codes.

Within the agriculture not only the crop but animal production can also be energy source in the form of biogas. Besides, the relevance of this group lies on that they serve as demand for agricultural crops in forms of littering. The animals relevant in Borsod are also implemented inthe model as subscripts.

Fuel types

The energy sector as the principal subject of this research has to be analyzed in details and its structure must be built including the process steps of energy production and consumption by fuel types and sectors of uses. Drawing a conclusion of the complexity of the system, the “fuel type” has been introduced as subscript as well. Table 24 lists the components of all three subscripts.

Table 24**:** Classification of subscripts in the biomass model

ANIMALS		AGRICULTURAL CROPS		FUEL TYPES
Denomination	**NACE code**	**Denomination**	**NACE code**	**Denomination**
cattle	01.21	Wheat	01.11	Coal
pig	01.23	Other grains	01.11	Oil
sheep	01.22	Maize	01.11	Natural gas
poultry	01.24	Potatoes	01.11	Electricity
other		Peas	01.11	Heat
		Sunflower	01.11	Wind and Water
		Sugar beet	01.11	Forest wood
		Silage and green maize	01.11	Forest byproducts
		Fodder crops rape	01.11	Straw
		Fruits	01.13	Energy plants1
		Grape	01.13	Energy plants2
		Others		Energy plants3
				Other1
				Other2

6.3. Introduction to model components and units

For a better understanding of model components, the variables have been signed with various colors and forms, summarized in Table 25. The units defined in the equation box are unique and their appropriate and consequent set up is very important. Basically the units most widespread found among the data and information gathered have been used. A list of most commonly used units is compiled in Annex I.

Table 25: Representation of variable types in the biomass model

Components	Description
Variable	Variable or component of the model
	Arrows represent connection and flow direction between variables
I Variable - Indicator	Variables starting with 'I' with purple background represent relevant regional indicators
To be changed	Those of the input variables which are to be changed when applying various scenarios
<Shadow>	Variables between angle brackets indicate shadow variables, which are defined elsewhere, not in the current sub-model
Sub-model connection	This sign next to the relevant variable indicates the connection to other sub-models
SUM-variable	Calculated summary of important partial output variables; summarizing subscripts or variables

6.4. Sub-models within the model

Sub-models are connected functionally through shadow variables (see Table 25), representing one single connected, dynamic and feedback system. The main sub-models are introduced hereon.

6.4.1. Population sub-model

As the size of population has a high correspondence with the consumption of energy commodities and other demands, it becomes a driving factor of several social and economic components; the demographic sector must be therefore represented and analyzed within the model. The population sub-model has been built to simulate the dynamic changes of the number of inhabitants within BAZ over time. The sub-model's structure is presented in Figure 73.

Inputs and data sources

Primary data are data used for start-year or historical time-series of the simulation. These data are taken from statistics or other sources, outside of the modeling. All primary input variables, which vary in time, need to be defined over the entire time horizon of the simulations (1990-2020). The model is based on major algorithms for births, deaths, emigration and immigration. These variables are based on an the review and synthesis of demographic literature and statistical data of previous years [Ksh,2004b], [KSH,2002]. The National population forecast database of Hungary (NÉPINFO) includes detailed source for population forecast until 2050 at county level [NÈPINFO,2006], which has been implemented into the model.

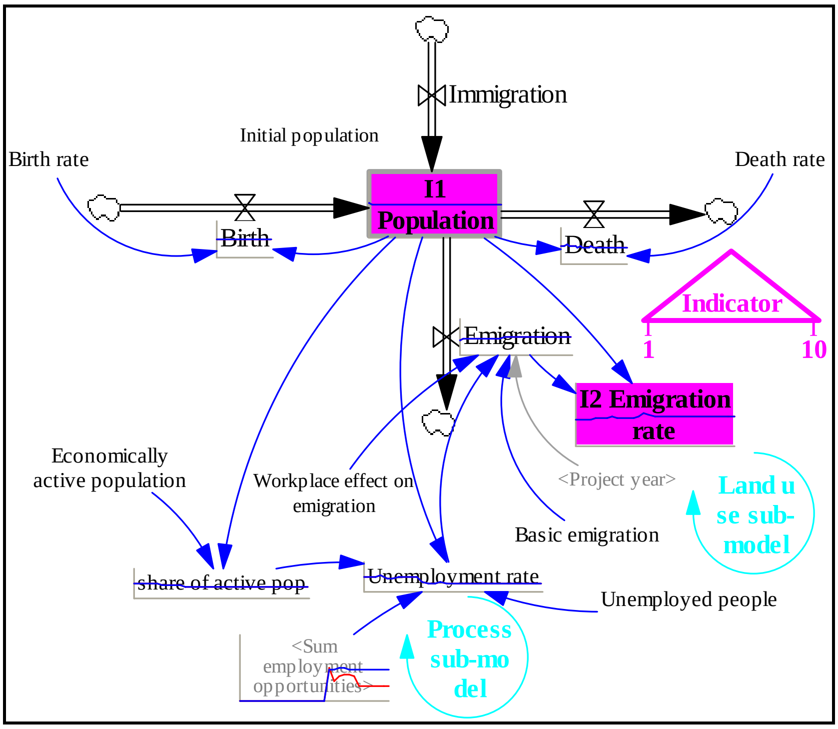


Figure 73: Graphical sketch of the Population sub-model

Besides primary input, there are those which are processed from the model itself through simulations, which are called **secondary or processed (shadow) variables**, which at the same time are intermediate outputs from other sub-models. It is not possible to define or give those data from outside because they are generated through equations and several interactions. For example the 'I Additional manpower' is a result of the Biomass process sub-model, linking it in this way with the Population sub-model. When applying scenarios, this decreases the unemployment and in this manner the emigration as well. Another secondary input is 'Project year', which is the intervention year of possible scenarios application, defined in the Land cover sub-model. Both connections are indicated on the model sketch with a comment shown in a loop clockwise shape and light blue color near the shadow variable (Figure 73).

Outputs, indicators and interactions

To define the quantity and relations among the sub-model components, equations within the model were given for all these output or result variables. The type of this variable is level, representing a stock, which is fundamental to generating behavior in a system [Ventana Systems Inc.,2006]. Stock only changes over time and the value it takes on at any time depends on the value it took on at previous times. Birth and death are influenced by their rates based on statistical historical and forecasted data, immigration, in turn, is given with a primary input variable. Emigration is further detailed in the model and selected as indicator, implemented also within the regional objective tree. The migration of people is influenced by given working and living conditions, which partially originates also from the energy sectors. In case more workplaces are provided in the county, for example as a result of exploiting local biomass resources (simulated in the Biomass process sub-model), it will have a retaining effect on the local population. Unemployment effect on emigration has been analyzed using existing data and statistical functions and a linear correlation have been found among them, which was implemented through the 'Workplace effect on emigration' variable.

The auxiliary variable[9] 'Time' refers to a variable predefined as lookup[10], where the driving factor is the time. The integral, endogenous population sector analyzes and addresses

[9] Any dynamic variable that is computed from other variables at a given time

[10] Lookup function makes it is possible to specify an arbitrary nonlinear relationship. Simply, a Lookup is a list of numbers representing an x axis and a y axis; the inputs to the Lookup are positioned relative to

demographic issues including the following [MI,2004]: the dynamics of total population, of birth and death and county-level migration. Components which influence the number of population, as well as the ones influenced by it are represented with the so-called causes and uses graph in the model (Figure 74).

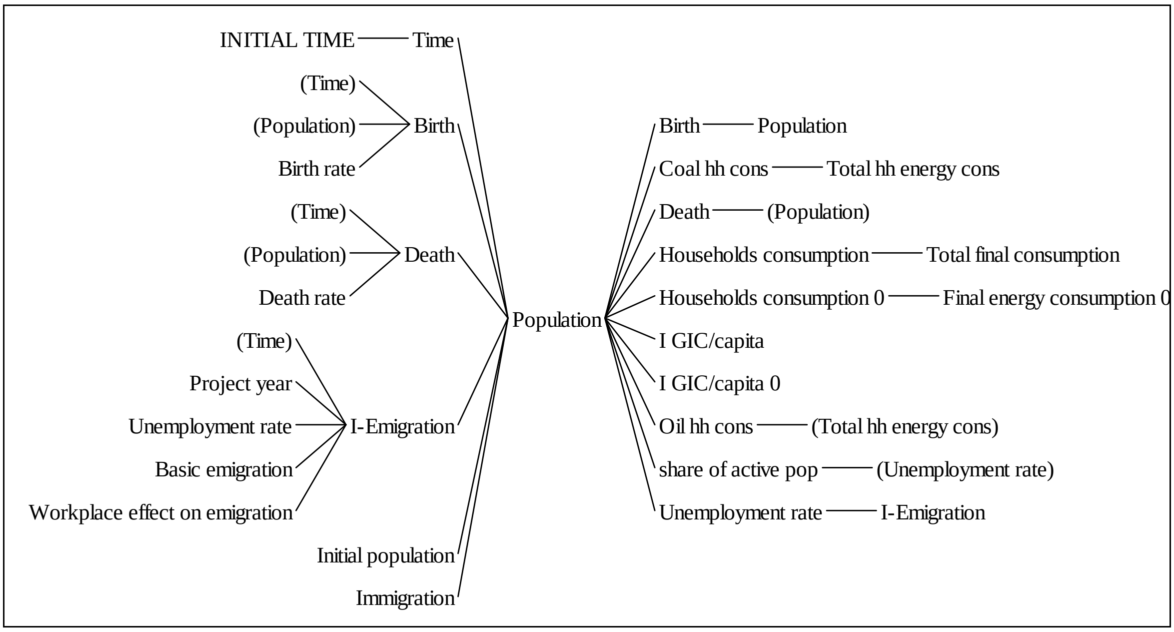


Figure 74: Causes and uses graph of 'Population' variable

6.4.2. Land cover sub-model

In order to be able to model future changes in land cover, the details of interactions among interested areas must be studied, the reasons of transformation from one type to another should be clarified and the regulative background should be viewed. In this way, the changes of relevant land cover types in Borsod are modeled from 1990 including the next categories:

1. Total area
2. Agricultural area
3. Forest area
4. Other areas (including water, artificial and the rest of the areas)

As the use of agricultural and forest biomass is the object of this study, emphasis is given to their influencing factors, changes and utilization alternatives, whilst changes in other land cover categories are included only simplified. The sub-model's graphical sketch can be seen in Figure 75 whilst its sources, components and construction with functions hereon.

Inputs and sources

As sources of this work, the database of the European Topic Centre on Terrestrial Environment (ETCOTE), the 'Territorial settlement plan' of Borsod [Koszorú,2002], the county development plans [NORDA,2006], Corine [EEA,2000], [EC,2004b] have been used. Data to primary input variables such as "basic agricultural area" and "total area" have been collected from county statistics [Ksh,2004b], and after several calculations the needed form was given to the model. Initial forest area, forest growth and density, in turn, have been given from the Hungarian Forest State Institute [ÀESZ,2006b], as it provides the most reliable data on forest management. An average for growth and density has been calculated, since all forests in Borsod are analyzed together, without distinguishing them by species, age, ownership or other factors. Shadow variable in the Land cover sub-model is the "demand to retrofit" defined in the Energy balance sub-model, which influences the energetic plantations, yield of which is taken from Hungarian literature [Bai,2006b].

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the x axis, and the output is read from the y axis.

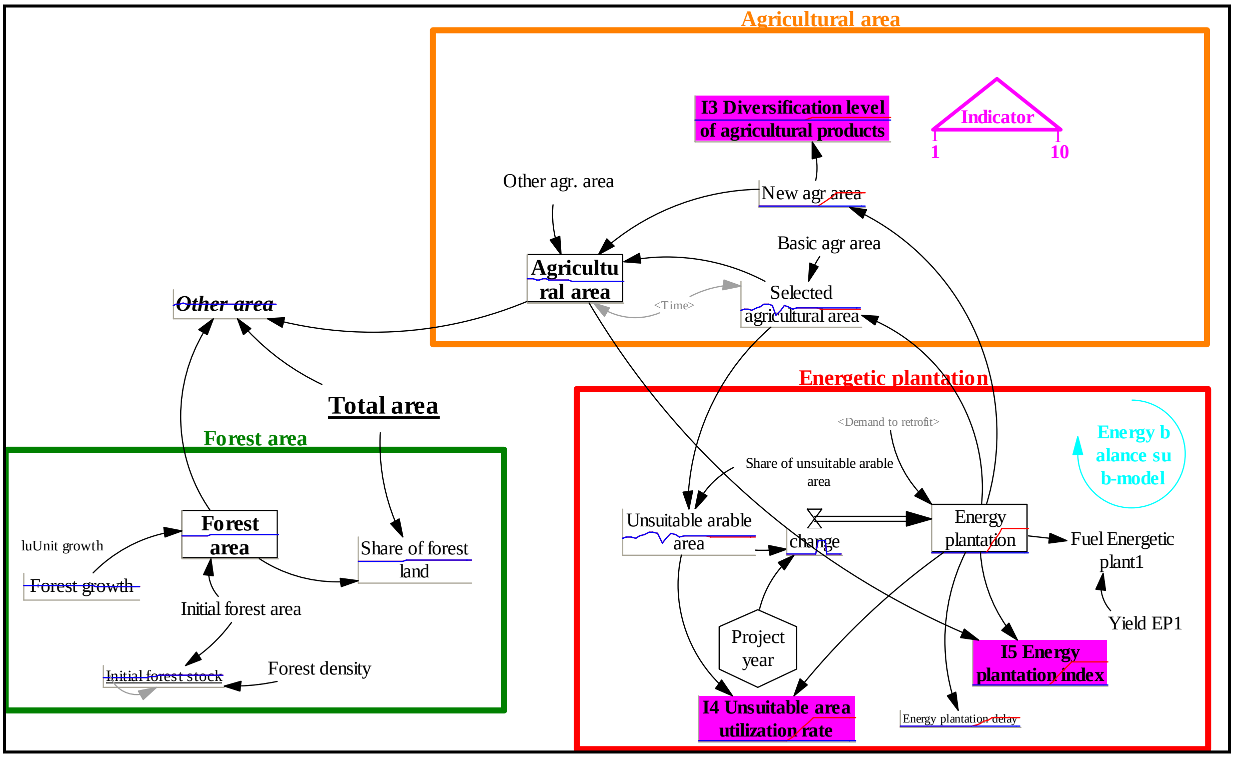

Figure 75: Structural overview of the Land cover sub-model

Outputs, indicators and interactions

The **total area** of the county (in 2006: 685,100 ha) is implemented given data from statistics and with the assumption of its future change according to the historical ones.

Agricultural area has further been divided by the produced crop types and shown by using the subscript group 'Agricultural crops' already introduced in Chapter 6.2. The subscript allows calculating the changes of various crop area (and production) simultaneously with the same method, however applying different numerical input values (size, yield, etc.). The variable 'agricultural area' is the summarized surface of selected and new areas, as well as others not considered within these two. 'Selected agricultural area' comprise the fields including the most relevant arable crops in Borsod, additionally the vineyards and orchards. The variable is built using the 'Basic agr area' variable, which is defined based on statistical data series from 1990. Since the variation of agricultural areas is influenced by numerous both biotic and abiotic factors: (soil type and quality, water, atmosphere, price elasticity, demand, supply, policy, support, trade, technology, labor availability, air pollution, use of fertilizer, weather, infrastructure, etc.) [EK,2005], [KSH,2003], [Wolfbauer,2005], [Barótfi I.,1998a], [Forrester,1998], their future simulation would require a very detailed analysis regarding all those factors. Doing so, however, is not in the centre of interest of this work, only the alternatives-related components are detailed. Future changes of related crops (wheat and maize) are therefore given according to scenarios assumptions (see later in Chapter 6.5), whilst other crops are not considered to be influenced by the selected alternatives in the sub-model.

'**Energy plantation**' refers currently to the size of new poplar energetic plantation (with more description in Chapter 5.6), but any other can be included. Within this section the variable 'Project year' is defined in a hexagon, which, according to definition, represents a variable changing when applying scenarios. The variable is dimensionless with constant type, fixing the range of the year to be applied between 2006 and 2021. This is a function facilitating future users of the model not to overflow the theoretically possible values, which is applied for several variables.

Forest area includes land covered by forests which is calculated by multiplying its extension at the first year of the simulation (1990) and the annual rate of forest area growth, based on the database of the State Forest Institute [ÀESZ,2006b]. Future growth has been calculated as average of the 30-years forest plan [ÀESZ,2006a], set according in the forest law [HR,1996]. That shows further increase of forests, however with a less rate (from 0.0025 to 0.0024). Forest area influences further components of the whole model, as shown in Figure 76.

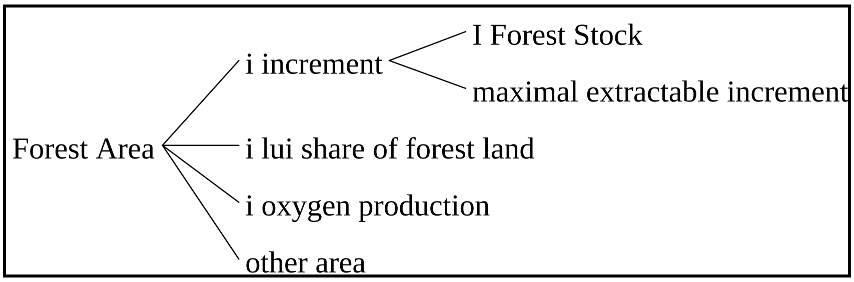

Figure 76: Variables depending on forest area

'Other area' serves as puffer variable comprising areas not included in previous categories, for example water bodies (rivers, fishponds, etc) and artificial surfaces, among others. Artificial surface refers to urban, industrial, commercial, transport, and other areas as defined in the Corine land cover database [EEA,2000] and county statistics [KSH,2004b].

The most important **indicator** of the forest sector is the share of forest land within the total area of county BAZ, represented by the output variable 'I Share of forest land'. Variable 'I Unsuitable area utilization rate' shows the changes in the use of unsuitable area, which is increasing over time through energy crop production, depending however on the different scenario applications. The annual area increase of energetic crop plantations is indicated by 'I Energy plantation increment' given in hectare, based on investment plans of Borsod. It is also an objective in Hungary, to increase the diversification level of the agricultural products, which is possible to follow through the implemented variable 'I Diversification level of agricultural products' when comparing the number of crop types produced by various scenarios. Land taken by the planned plant is not implemented within this work, because it is not representative (2.6 ha in Scenario 2), however, especially when establishing it within an area of local authorities, it is a positive aspect of land use. Additional effects could be the establishment of industrial parks in the region.

6.4.3. Agriculture sub-model

The Agriculture sub-model has been built and implemented into the whole dynamic system of the regional biomass use in order to show the system and analyze the positive and negative effects of these alternatives.

The sub-model simulates, on the one hand, the agricultural crop production, overproduction and residues, and animal production on the other hand, with the following subscripts, whilst the whole structure of sub-model is shown in Figure 77:

- Agricultural crops: wheat, other grains, maize, potato, peas, sunflower, sugar beet, silage and green maize, fodder crops, rape, fruits, grape and others
- Animals: cattle, pig, sheep, chicken and other.

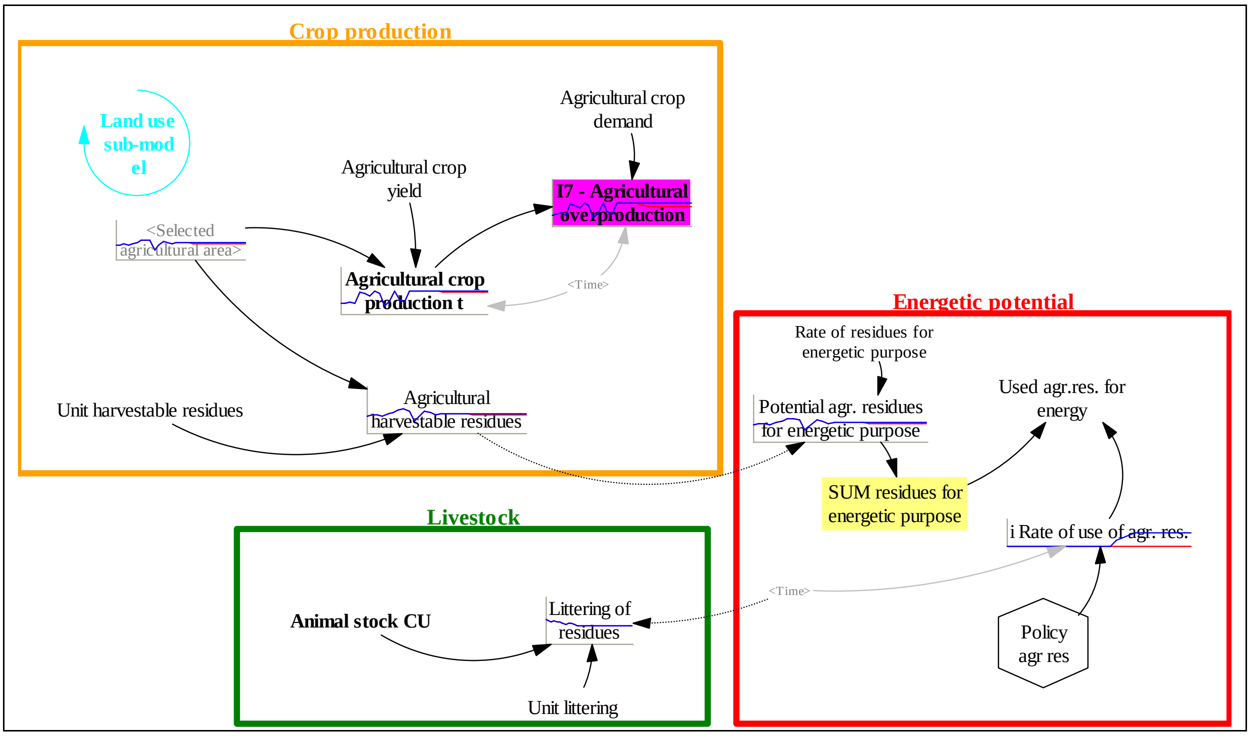

Figure 77: Graphical sketch of the Agriculture sub-model in Vensim

Inputs and sources

Statistical yearbooks of Borsod County [Ksh,2004b] served as a source of specific data with time-series concerning e.g. crop yields and livestock size. Agricultural crop demand is influenced by various factors, like prices, number of population, animal stock, export conditions, support, among others [Shone,2001]. Within this work it has been estimated based on national average of consumption, taken also into consideration the overproduction rate. To define residues and their harvestable amount, scientific literature and projects materials [Bai,2002], [Kaltschmitt,2003], [Barótfi,1998], [MTESZ,2001], [Iparterv,1998] have been analyzed. However, to determine the energy potential of residues, some further spread sheet calculations have been performed with county-specific data, considering losses by harvest and collection, demand for animal feeding, littering, soil-improvement, industry etc., as well as the role of the farms' size in the feasibility of residue collection. Results of the calculations can be viewed in Chapter 4.6. The shadow variable 'selected agricultural area' serves as a secondary input for the production calculation and connecting the Agriculture and the Land use sub-models.

Outputs, indicators and interactions

The **agricultural production** is calculated by multiplying the extension and yield of selected crops in tons. To show and analyze changes the addressed differences of production and demand over time, an indicator – 'I - **agricultural overproduction**' - has been implemented into the sub-model, calculated as the difference between the production and demand for each subscript (crop). Further indicator in this sub-model is '**I used agricultural residues** for energy', which is influenced by current policies in the sector. For modeling the energetic potential of residues (e.g. straw, corn-stalk, sunflower-stalk, lopping and grape cane), the already mentioned multiplication factor 'rate of residues for energetic purpose' has been applied. As result, the summation of all residues by agricultural crops subscripts gives the value of a new variable for the straw of fuel type subscript. '**Littering of residues**' represents the residue demand for animal littering[11].

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[11] Several other components could be taken into consideration, for example technology, labor quality, fertilizer, irrigation effects on yield, capital formation and depreciation. However, analysis of these components does not represent the goal of current study, therefore are not integrated within the developed model.

6.4.4. *Forest sub-model*

There are several forest models available, for example Envision Environmental Visualization System, Fiber in the forest, Harvest Version 6.0, Landis-II Forest Landscape Simulation Model, Pipestem, RBSim Forest Recreation Behavior Simulator, SILVAH 5.1, etc.. All of these, however, simulate effects of precipitation, soil fertility, water content, acidification, details of the species of trees, health and age, etc., which is not the goal of the developed Forest sub-model. This is to have a realistic picture of the average forest extension and growth in order to analyze the possibility of using the available wood and residues for energetic purposes. The sub-model includes all biomass produced in the forest in conjunction with which are removed, for economic or silvicultural reasons in precommercial thinning or left in the fields, but are possible collectable. Besides, the model shows the temporal changes of the total forest stock, oxygen production, clustering their variables according to the following sectors:

- Increment
- Decrease
- Potential

The whole sub-model structure built around these sectors is displayed by Figure 78.

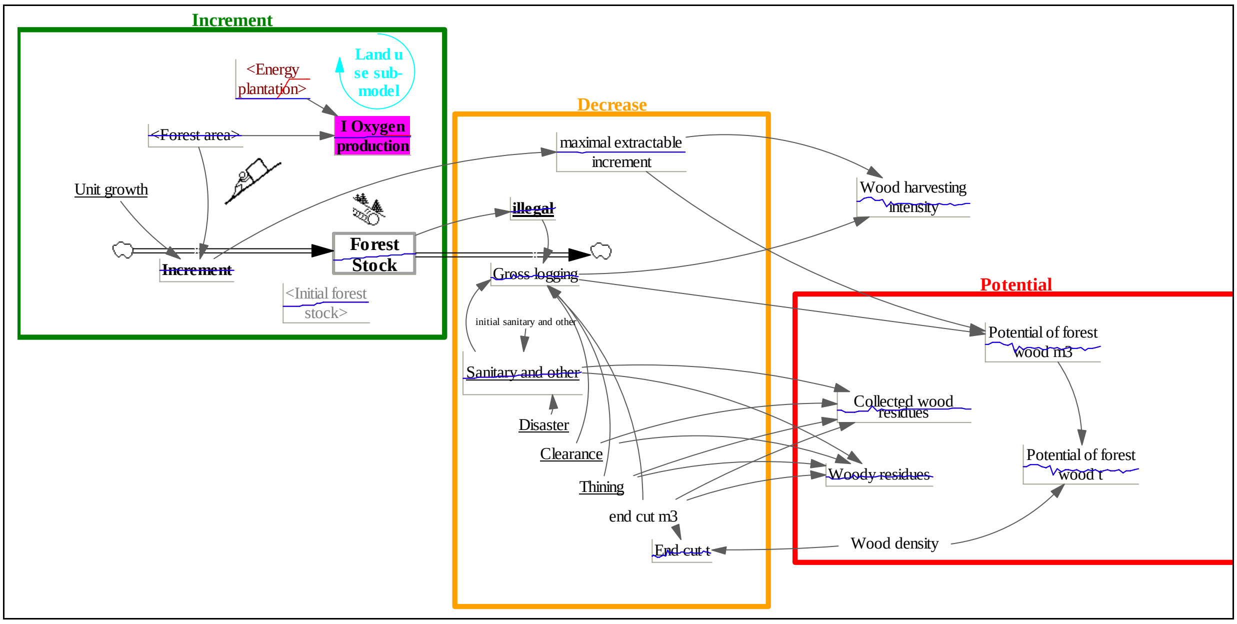


Figure 78: Overview of the structure of the Forest sub-model in Vensim

Inputs and data sources

Specific information and historical time-series figures of Borsod's forests and their management have been collected via personal interviews by the local office of the Hungarian Forest State Institute in Miskolc [ÀESZ,2006b], and by the Északerdő Zrt. forest company [Èszakerdö,2006]. Relevant literature [ÀESZ,2002], [Barótfi,1998], [HR,1996] and homepages have also been studied to acquire the needed knowledge, e.g. the terminology of the forest sector. The named statistics have been used for giving the amount of forest growth, average mass of one m^3 wood [Marosvölgyi,2007], and components of increment and decrease. The central variable of the sub-model is the indicator '**I Forest Stock**' showing the total annual wood stock of the forests in m^3 within BAZ county. The initial stock is given directly for the first year of the simulation, coming from the Land-cover sub-model. The increment increases this stock, whilst it falls with the extraction of wood (gross logging).

Output

Woody clearance (wood of dismade or for special purpose), thinning (generally two times in the lifetime of a forest), sanitary and other lumbering for previous years and those values have been kept in the future. The latter determined as depending on the initial extracted amount and disasters within the sub-model. Illegal logging is given in percentage of the forest stock, based on specific literature estimations and statistics (the change of methodology of Hungarian statistics is not appearing in the model, namely that prior to year 2004 the illegal extraction was not considered, because firewood amount was calculated based on selling, whilst after 2004 it was estimated). Historical end cut (wood extracted for industrial or firewood purpose) was defined based on statistics and future amounts were given according to the 30 years-plan of ÀESZ. All these sum up the gross logging, shown in Figure 79, given in m^3, but some variables have been converted into tones using the density of wood, mainly shown in the name of variables (such as ‘end cut t’ or ‘potential of forest wood t’)[12].

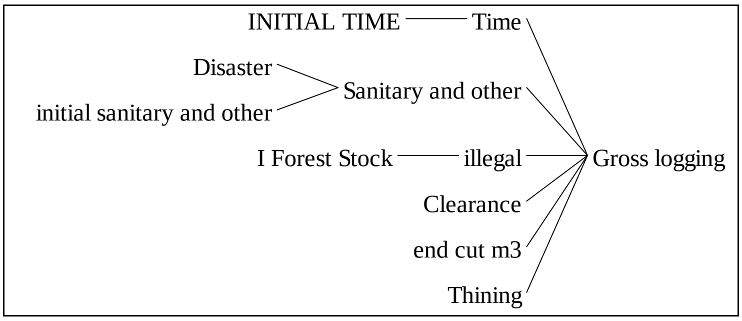


Figure 79: Components of gross forest logging

On the other side of the forest stock stands the yearly increment, defined by multiplying the forest area (shadow variable from Land cover sub-model) and the average growth characteristic to the BAZ forests. According to the sustainable forestry principle, based on the LIV/1996 law [HR,1996], the extractable amount of wood cannot exceed the annual increment. To quantify that amount, the primary designation of forests was taken into consideration, viewed in Figure 80. The variable ‘maximal extractable increment’ includes the total annual growth of the economic forests; besides 50% of the increment is within protected areas with restricted use, which represent quantitative limitations of the model.

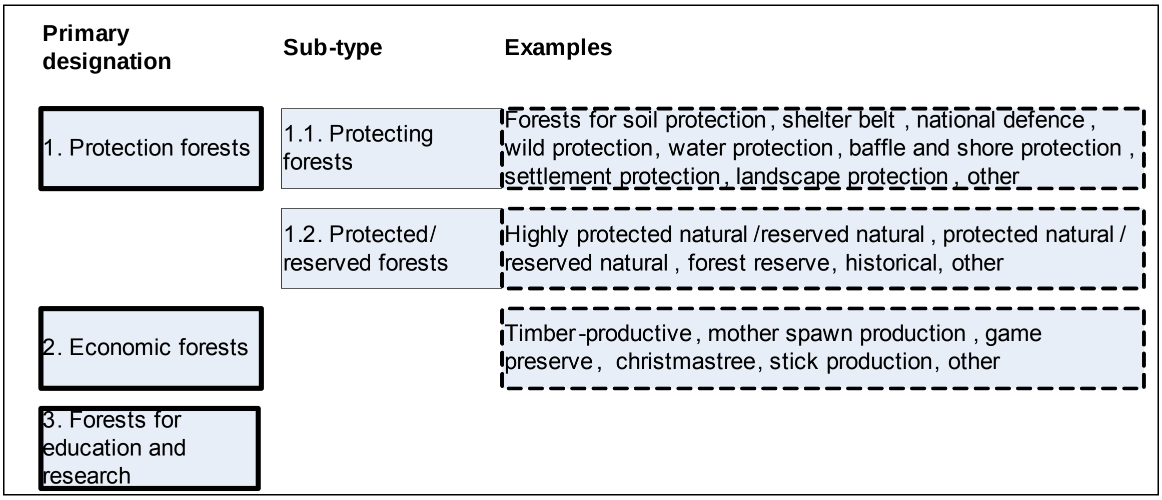


Figure 80: Forests distribution by their primary designation

[12] Several further factors might influence the logging activities, such as the type and distribution of trees, age of forests, primary designation, ownership, subsidies, wood demand and market (clearance especially depends on subsidies and firewood demand, sanitary depends much on weather, diseases and insect attacks). However, those are not included in the model since, as mentioned before, such detailed analysis is not the purpose of this work.

Based on information from forest companies [Èszakerdö,2006], not the whole amount of the gross logging is extracted from the forests by the companies, but a significant share (mainly all wood material from first thinning, clearance and sanitary works, as well as arising from the end cut and second thinning) remains in the forests, taken into account by the variable '**woody residues**' (see Eq.9). The major part of these residues, however, is collected by the local population for firewood or serves nature protection purposes. Gross logging not always reaches the annual limit; in such cases more wood material is available for lumbering, which represents further potential use ('I potential of forest wood m3'). One further indicator has been implemented to display the forests 'oxygen production'. These two indicators will be viewed in the next Chapter to compare scenarios achievements.

$$WR = 0.25 * EC + 0.25 * 0.5 * T + C + S \qquad \text{Eq.9}$$

WR= Woody residues; EC=End cut; T=Thinning; C=Clearance, S=Sanitary and other

6.4.5. Energy balance sub-model

Energy balance is the most complex and detailed sector in the model representing the production of energy commodities and the consumption by sectors and by fuel types. The sub-model includes the full chain of fuel production, conversion, energy commodity supply, trade and consumption, so that the county's whole energy balance is reflected and can be analyzed, even though simplifications have been made (See Chapter 6.5.7). The sub-model has been built round three main group differentiated within the sub-model: indigenous production of fuels (fuel production); fuel conversion in heat and/or power plants to electricity and heat (energy production) and total consumption of energy commodities (energy consumption), viewed in Figure 81.

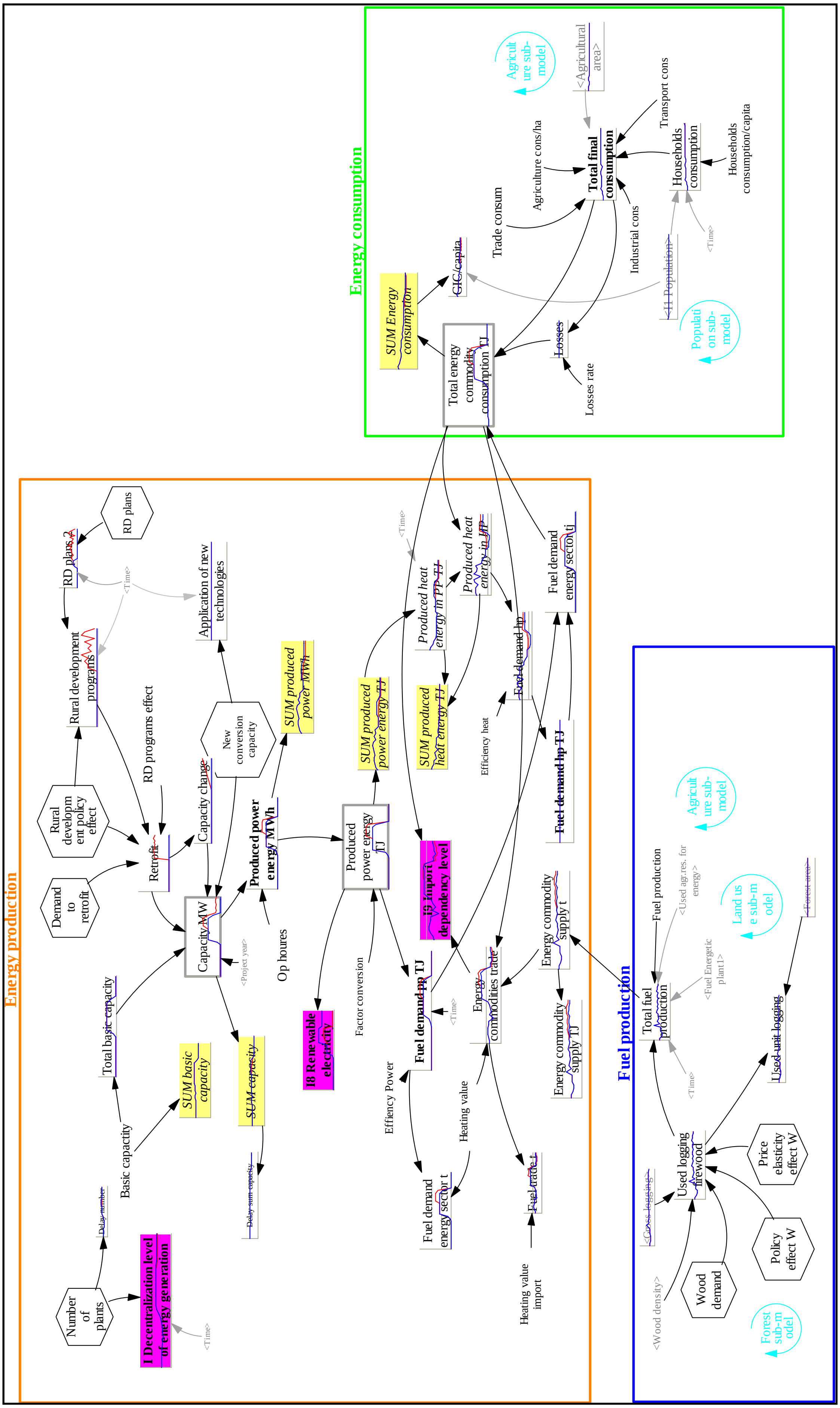


Figure 81: Graphical representation of Energy balance sub-model

6.4.5.1. Fuel production

Input data

Data for modeling the total fossil fuel production of the county is primary input, taken from mining statistics [Schmotzer,2004] [Kontsek,2004], [Kárpáty,2004], introduced also in Chapter 4.8. The variable 'Fuel production' includes the extracted amount of fossil energy carriers in Borsod, where oil and gas are zero, as only good quality coal and lignite mines exist in the area. Biomass fuel production is a secondary input, coming from the Land cover sub-model, which was implemented within this structure via a combination of subscripts, namely one subscript as output serves as input to another subscript. Future changes are mostly influenced by the actual renewable policy and planned activities in the county. The produced amount of the different types of biomass for energetic purpose is calculated in further sub-models. The variable 'I gross logging', used to get firewood production, sets up a connection with the Forest sub-model, whilst 'Used agr.res. for energy' and 'Fuel energetic plants' include the amount of agricultural residues for energetic purpose as well as wood fuel from energy wood plantations are outputs of the Agriculture and Land use sub-models. 'Wood density' is a further shadow variable, however it is a constant value not calculated but only defined in the Forest sub-model. Some variables are given with hexagon, which means that they can be changed when applying various scenarios (as introduced in Chapter 6.3). Those, such as policy effect or price elasticity can be defined outside Vensim, for example in Excel environment, using historical data series and correlation functions. The identified correlations than can be implemented into the model.

Output

This section summarizes the extraction of primary fuels from fossil reserves and biomass sources using the variables introduced before and displayed in Figure 82.

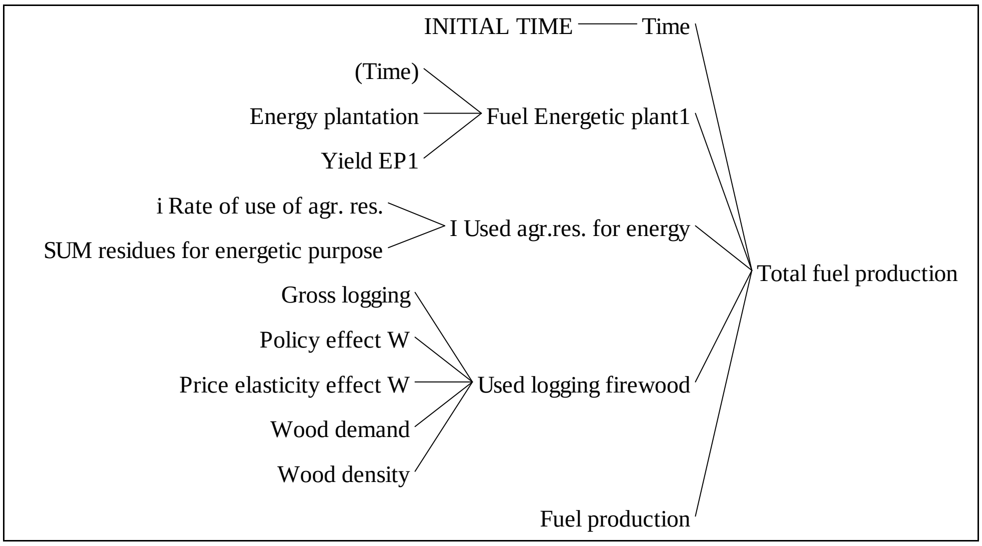


Figure 82: Components of total fuel production within the Energy balance sub-model

6.4.5.2. Energy production

Policy, price elasticity and demand for wood can be implemented through effect variables - in hexagon - according to future changes.

The indicator 'I used unit logging' implements the used firewood, and shows its in relation to one hectare forest land (t/ha).

Input data

For modeling the power and heat production, the basic capacities, the annual operation hours, production figures, losses, conversion factors and efficiencies of the public and industrial power and/or heat plants both big and small (<50 MW_{el}), have been implemented as primary input, most of them by fuel types. Time-series and constant data have been collected and processed from several sources [MEH,2006], [MVM,2002], [MVM,2005], [Mavir,2005].

Downscaling and estimations about small power plants was also necessary, as they were not available from the whole time-period of the modeling. As an example of such result Annex XI. summarizes collected and processed information about plants in Borsod.

Capacity in this sub-model refers to is the installed electric capacity of power and CHP plants expressed in MW. The basic capacity, given with a primary input variable by fuel types based on electric energy statistical yearbooks (MEH, 2005; MVM, 2002) and gross capacity plans of the national power system [Mavir,2005]. Implementation of new technologies and technology changes may be influenced by policy effects, rural development programs as well as by the energy demand, which factors have also been considered, as shown in Figure 83.

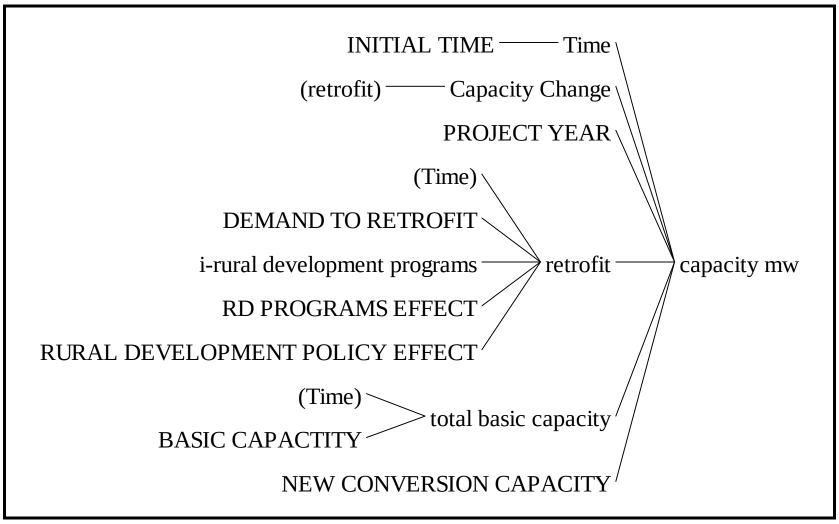


Figure 83: Model components influencing directly or indirectly the variable “Capacity”

All primary input variables, which vary in time, need to be defined until the time horizon of the simulations according to the different scenarios. In case of no available concrete information about the future development, estimations based on historical data have been applied, for example, with proportional relations or regression functions using the relevant time series of historical data. For this purpose, regional plans, laws, regulations, operation and capacity plans of energy plants, as well as existing trends and predictions from literature have been studied and variables as effects were implemented.

Output

Most variables in the Energy balance sub-model are subscripted by fuel types, i.e. they contain in parallel the values for every fuel and energy types. Therefore ‘SUM’ variables indicated with yellow background have been implemented to show the sum of these values. Variables related to heat plants are indicated with “hp” after the variable name, components in connection with power and CHP plants are shown together and indicated with “pp”. Some outputs need to be expressed both in natural (t, m³) and energy units (TJ, MWh); thus for the sake of transparency the unit of measure is represented at the end of the variable name.

The main output ‘**Produced power energy** Mwh’ covers the realized electric energy fed into the national power grid, i.e. the total generated power reduced with the own consumption of the plants. It is a product of the electric capacity and the operational hours expressed both in MWh and in TJ.

CHP plants produce both heat and power. To get the generated heat amount, the share of heat to the produced power has been used. **Heat generation** in heat-only plants is calculated as the difference of the total heat consumption shown by the ‘Total energy consumption’ variable (heat subscript), and the produced heat in CHP plants.

For a complete balance of the energy plants, **fuel demand** for the conversion processes has been modeled by fuel types as well. As it was mentioned, for this sake the efficiency of the conversion has been considered. In case of power generation the average efficiencies of the operating power and CHP plants have been applied, referring of course to the amount of power fed into the national grid; by heat-only generation a value characteristic for the Hungarian public heat production has been used. The fuel demand obtained in TJ is converted and displayed also in tones, using the average heating values of the each fuel type.

Relevant **indicators** are the “I energy commodities trade” and ‘I import dependency level’, the ‘I renewable electricity’ and the ‘I energy decentralization level’ are important and often used indicators of the energy production sector. The indicator ‘I rural development programs’ influencing retrofit and new conversion capacity represents how regional objectives and efforts can effect technology changes and the establishment of new energy plants. The number of new plants is represented by the model output ‘application of new technologies’. In case the supply of energy commodities exceeds or if it is lower than the total energy consumption in a region, fuels and energy must be imported or can go to export. The indicator ‘I energy commodities trade” shows the energy commodity surplus or deficit within county BAZ in TJ. Finally, the ‘I Import dependency level’ indicator is the quotient of “I energy commodities trade” and “total energy consumption TJ’, and shows how big the county’s dependency on energy commodities is.

6.4.5.3. Energy consumption

Input

Primary data in relation to the **distribution losses** have been collected from the communal statistics [Ksh,2004b], or defined by iterative calculations and estimations. These estimations are based on the detailed Hungarian energy balances from the time period 1990-2004 [EK,2006a], as well as on discussions with experts. Distribution and transmission losses refer to losses in gas distribution and heat and electricity transmission. Finally, sectoral consumption and losses rate are primary inputs.

Output

The energy consumption part of the model includes the total consumption of fuels and energy types within the region. Its main output ‘Total energy consumption’ is the sum of the total final consumption (non energy use + final energy consumption) and distribution and transmission losses as well as the fuel demand of conversion processes in energy plants which is an output of the Energy production part of the sub-model.

Total final consumption covers energy and fuel use for heat purposes as well as fuel use for non-energy purposes by the sectors of industry, services and trade, agriculture, households and transport. The energy sector’s fuel consumption for conversion processes is the sum of the fuel demand of power and CHP plants and that of heat-only plants, described in the previous section. The energy sector’s own consumption is included indirectly in the total energy consumption, as the amount of generated power and heat appears already reduced by the own consumption of the energy plants in the model. ‘I GIC/capita’ refers to the gross inland energy consumption per capita

6.4.6. Process sub-model

To evaluate the use of agricultural and forest biomass for energy purposes from the viewpoint of sustainable regional development, its complex effects - advantages and disadvantages - must considered and analyzed. The Process sub-model has been built just for this purpose (see Figure 81): it quantifies the present and future changes of selected economic, social and environmental factors - being of high relevance and importance in county BAZ - resulting from the biomass-to-energy process. However, processes in relation to other fuels, e.g. fossil fuel conversion to power, are also included. Besides these vertical components, the fuel-to-energy processes comprise a broad range of steps according to the several feedstock types, which are horizontally represented within the Sub-model: production (P), extraction (E), transport (T) and conversion (C). By production, the establishment, cultivation and harvest of energetic plantations is studied; whilst biomass extraction refers to logging of wood and collection of different biomass by-products. Fuel transport covers road transport, and fuel conversion includes the construction/retrofit of energy plants and conversion of fuels into heat and electricity within them.

The following conception was used for modeling: every impact can be calculated as the product of the activity rate and the impact factor relative to it. Activity rates in accordance with the process steps are for example the area of energy plantations, the extracted amount of wood and by-products, the transport service and the annual produced amount of electricity. The impact factors (identified as ‘Unit’ in the variable name) give the manpower demand, the costs and the emitted amount of pollutants per activity unit.

From the graphical sketch of the sub-model, it can be realized that it contains a great number of shadow variables coming from the Forest, Agriculture, Land use as well as from the Energy balance sub-models. As a matter of fact, all activity rates are represented by these secondary inputs, so only the factors needed for the impact calculations have been implemented as primary input data in the Process sub-model. The three main outputs at the end of the horizontal ranges serve as indicators displaying the temporal changes in manpower, total energy production costs and emitted carbon-dioxide. As mostly biomass-related processes are considered in the sub-model, from a regional point of view, the differences between the simulated scenario-results must be analyzed and regarded as additional effects, instead of absolute numbers. The following description provides detailed information about the sub-model’s components, inputs, relationships and equations.

6.4.6.1. Manpower

High unemployment within BAZ represents one of the major social problems and therefore it was included within the model. Biomass utilization for energy purposes creates additional workplaces as the whole energy process takes place within the region, despites fossil fuels’ use, which is mostly imported from large distances. Changes in the employment can be followed within the model through the already described vertical axis, namely through the whole biomass chain.

Input

Sources for deriving **manpower** needed for plant construction and retrofit have been taken from literature of the same technology and capacity, for the conversion from existing plants statistics and Electric Energy Statistic Yearbooks [MVM,2002], power plant operation plans [Mavir,2005], for the transportation and logging from personal discussions and calculations based on articles [Èszakerdö,2006], [Umweltbundesamt,2005].

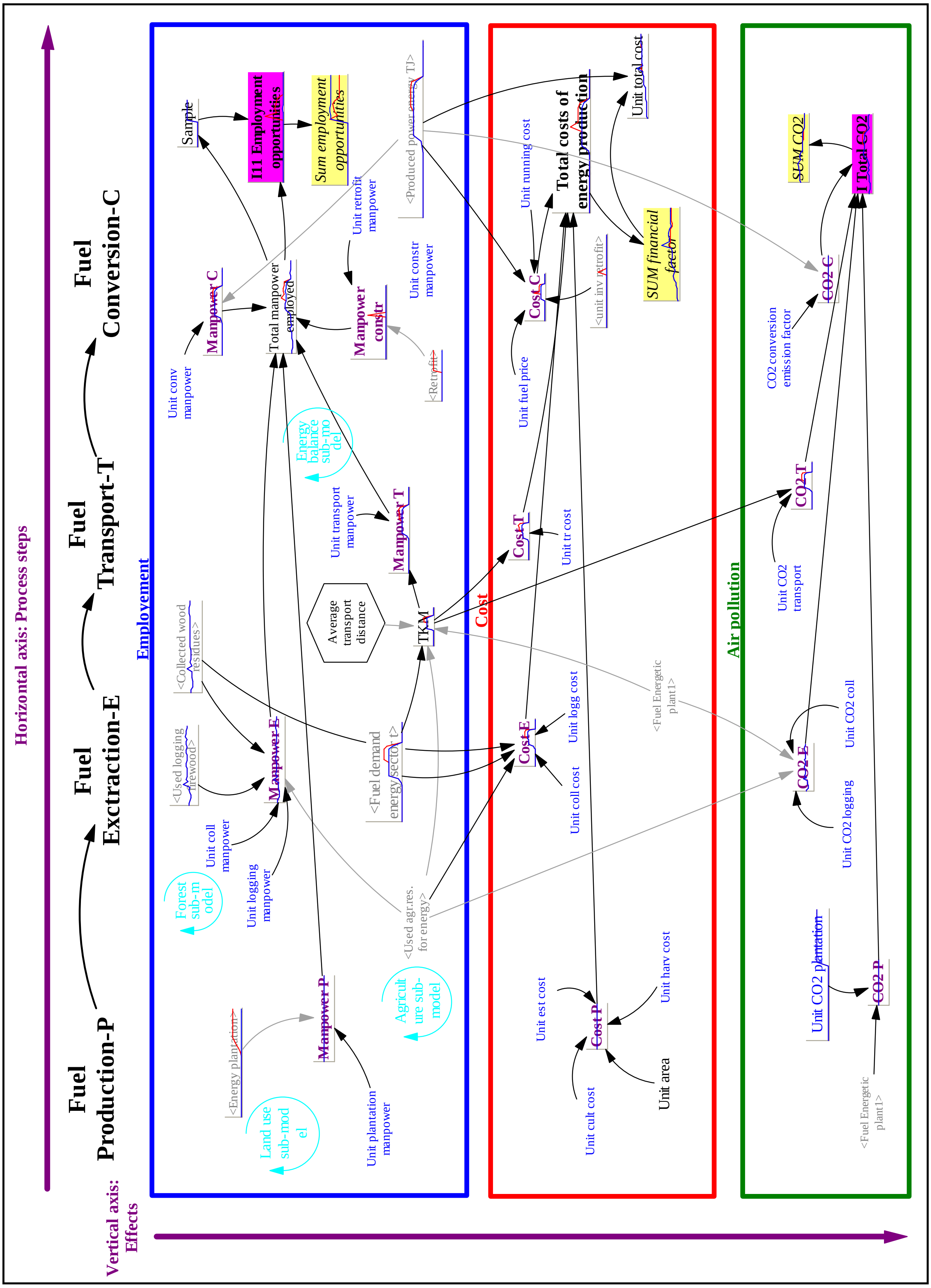


Figure 84: Graphical sketch of the Process sub-model in Vensim

Output

Production (P) considers only the amount of energy plantations, since fossil fuels are no longer extracted within the county. The needed manpower for energy plantations increases with the plantation area defined in the Land use sub-model. The labor demand for one hectare consists of the establishment, cultivation and harvest works in an annual average concerning the plantation’s life span (soil and area preparation are not considered). In order to get the transport manpower the transport service has been multiplied with the unit manpower demand. Transport service expressed in ton-kilometers is defined as follows: the weight in tons of material (here the biomass fuel demand of the energy plants) transported multiplied by the number of kilometers driven. The driven kilometers can be influenced through the average transport distance, implemented as a primary input variable into the sub-model. The related causes diagram in Figure 85 displays variables affecting the workbench variable ‘manpower t’.

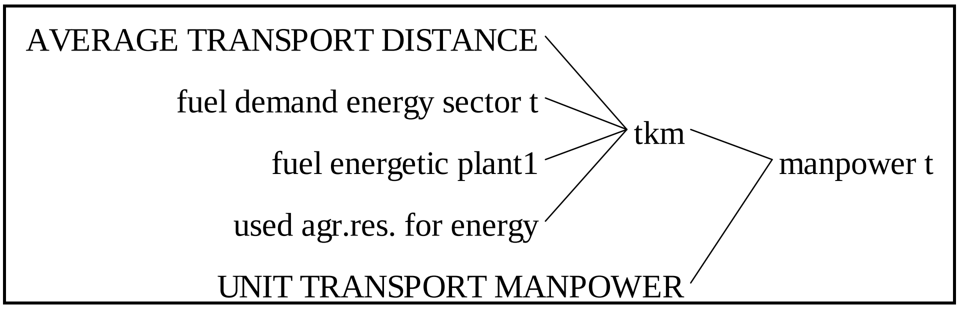


Figure 85: Causes graph for the variable “manpower t”

In case of fuel switch in an energy plant, labor to further transport of the previous fuel will not be needed so transport manpower decreases at the same time. This fact has been neglected as the defined scenarios assume biomass use despite fossil fuels which are normally transported by train, or through pipeline.

Employment in **energy plants** differs also by feedstock type, as e.g. diverse treatment and preparation steps are needed by wood or coal. The unit factor has been given related to the produced amount of power expressed in TJ, which is defined in the Energy balance sub-model by fuel types. New conversion capacity and the retrofitted capacity given in MW and calculated in the Energy balance sub-model are only taken into consideration in case of biomass scenarios, where the intervention year is given by the variable ‘Project year’. The sum of the employed people in the considered processes is represented by the indicator ‘I employment opportunities’. Changes in manpower have an effect on emigration and on the development of population, shown in the Population sub-model, which in turn affects energy use, creating in this manner a feedback loop, shown partially in Figure 86.

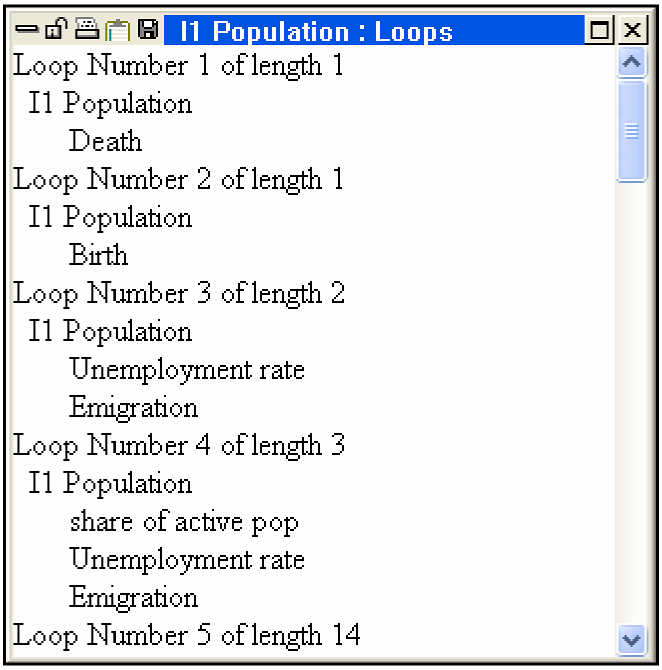


Figure 86: Representation of selected loops of feedback within population variable

6.4.6.2. Cost

Input

Data sources for the **costs** of establishing energetic plantations are Hungarian literature from [Tar,2005a], [Bai,2006a], [Bai,2006b], and [Marosvölgyi,2005b] and data from the Hungarian Biomass Association. For defining costs of logging, fuel extraction and transportation, own calculations have been processed based on interviews [Èszakerdö,2006], wages from Statistical Yearbooks of Borsod [Ksh,2004b], and literature ([Unk,2005] and [Tan,2002]). Subsidies are given from FVM Decrees, like [FVM,2004a] and [FVM,2005]. Fuel and running costs are mostly taken from MVM [MVM,2002] for solid fuel and energy production and estimated based on the fuel prices for oil. Future costs are mostly estimated by diesel and oil past changes, given by literature or, if no information were available, regression functions and proportional relations based on historical time-series data have been used.

Output

The modeling of additional costs happens similarly to the above described manpower demand, with some variance. The costs of **producing** energy crops include the first year's cost of establishment, annual cultivation costs as well as harvest costs from the fourth year assuming a plantation with a 4 year harvest frequency.

Exchange rates between Hungarian Forint (HUF) and Euro (EUR) have been taken from official statistics in Hungary (KSH) after 2002, and from the database of the European Central Bank (ECB) before 2002.

Extraction and transport costs of biomass are modeled in the same way as manpower demand, whilst some variation can be realized regarding conversion. Fuel cost takes into account fossil fuels, where the costs of extraction and transport have not been included by the previous process steps. In this manner, the financial effects of feedstock replacement could be considered as well. Inflation is taken into consideration by the technologies.

For defining future fuel costs, Hungarian literature and forecasts have been reviewed, and the applied change rates have been adapted to this study also. Several factors affect future oil prices in Hungary, among others the international market prices, taxes, price fluctuation and availability of raw material, current rate of Forint, transport conditions and distances, importance and price of environment, technical and technological development, demand and supply (personal conversation with Bai). Applying linear regression function based on this information, a 7.4 % yearly continuous increase was used for gas prices after 2005, according to personal conversation with Attila Bai. Oil prices have been estimated with linear extrapolation based on base data, which, with its averagely 3 % yearly increase, correspond to the prognosis of the Commodity Price Database [Gács,2006]. Similarly, with linear extrapolation the coal price has been calculated until 2020.

Further components, such as the costs of establishment plan or of an environmental impact assessment, what must be prepared for all plants larger than 20 MWe or 50 MWh, according to the [FVM,2001] are not taken into consideration, as the technology and infrastructure investment neither, because it is supposed to be in the hands of the investor. Further exluded components are the contract costs, tax outage, excise, consumption tax [Àngyán,1998]. It also must be mentioned, that transport, collection and other costs of the process mean income for local people, therefore, from a regional aspect it cannot be considered only as disadvantages [Bai,2006c]. (This is incorporated in the value added)

6.4.6.3. Air pollution

Environmental data sources are based on scientific literature [Sims,2004], [Bai,2002], [Kaltschmitt,2000]) databases [Umweltbundesamt,2005] and conference materials. In several cases data have not directly been taken from sources but were calculated outside of the model, in pre-determined Excel Worksheets, based on these sources.

For the preparation of the CO_2 emission, the dynamic model built by [Kakucs,2006] has been used, with its definitions and data. CO_2 emissions are calculated according to the European standard method EMEP/CORINAIR [EEA,2003] using the equation below:

$$E = AR * EF \qquad \text{Eq.10}$$

E=Emission; AR=Activity Rate; EF=Emission Factor

Gases emitted during the construction have been neglected as they are irrelevant in comparison with the operation emissions. The sum of each process step results, serve as **indicators**, such as the ‘I Total CO2’. Mitigation of CO_2 emissions and climate change is an accentuated objective of several agreements, laws and regulations, and is apparently a big advantage of biomass use, as emission factors of the end use (combustion) are considered to be zero. Whether the CO_2 balance is still favorable regarding the whole biomass process, e.g. energy crop production on huge plantations can be analyzed with the use of this model.

Further develop of the sub-model can be through implementing and analyzing of further important impacts, concerning financial (e.g. CO_2 trade), land use, technological, know-how and R&D aspects Also further calculations has to be performed in order to give a more precise prediction of the future development of impact factors, especially of cost factors.

6.4.7. Regional economy sub-model

The Sub-model Regional economy is referring to the representation of main economic circumstances in the energy sector. Besides the energy-related **costs**, coming from the Process Sub-model, the **gross margin**, and **value added** are main outputs, presented in Figure 87. It must be emphasized once again, that there is no intermediate sale taken into consideration between the fuel production and the energy generation.

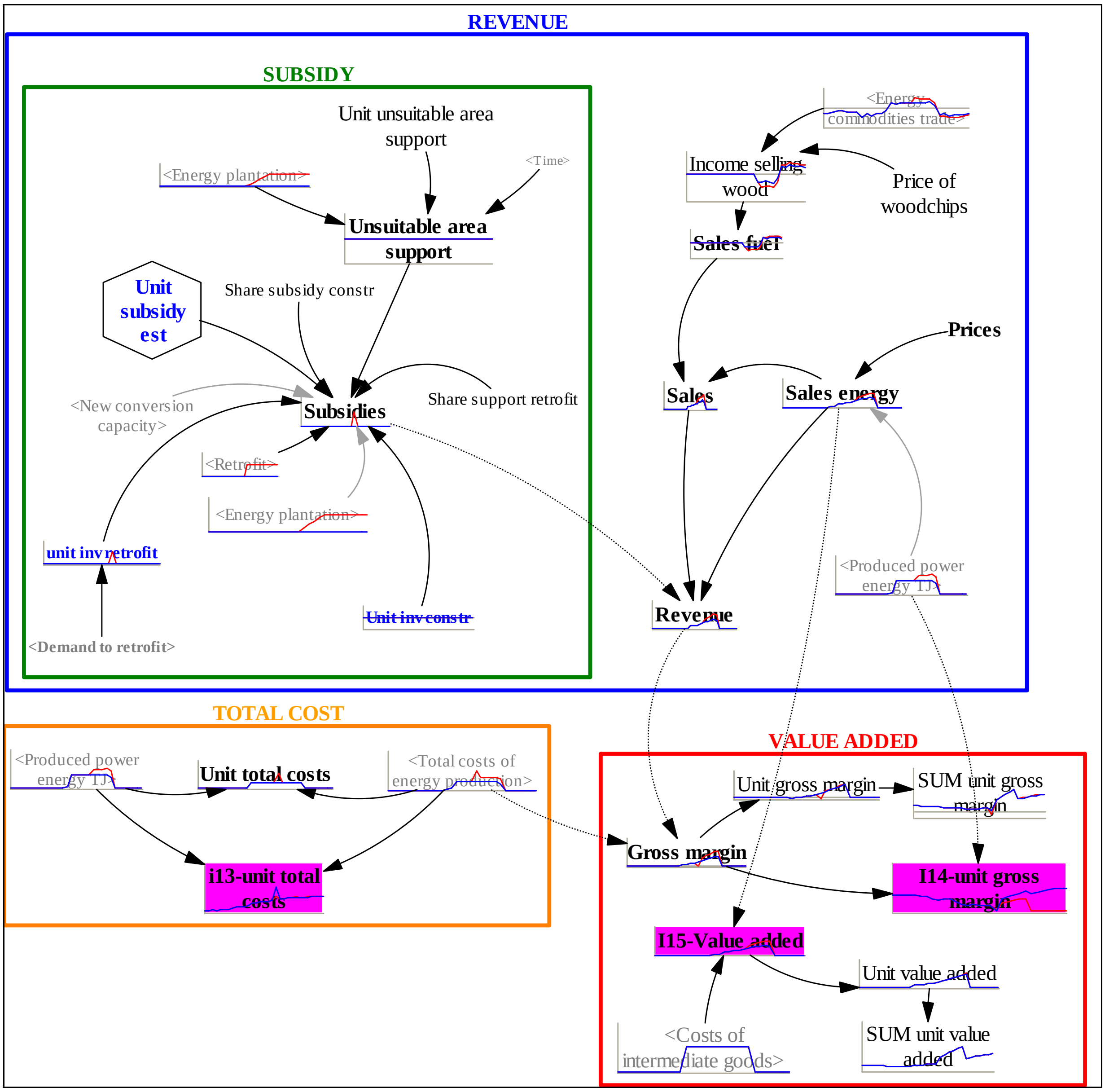


Figure 87: Representation of the Regional economy Sub-model in Vensim

This sub-model analyzes the biomass chain starting at fuel production until the energy generation stage, the **costs** of which are calculated. Additional technology and machinery developers and producers are not considered, as it is supposed that investors own or rent them. The costs of the consumer sector, so the market prices of heat and power for the households, industry etc. are also excluded of this study because the chain is analyzed until the plants. Costs are calculated in the Process sub-model and are used as shadow variable. Components of support systems can be distinguished from the view of beneficiaries: energy producers, technology or process developers, fuel producers and energy consumers. There are several **subsidies** and support schemes in Hungary for increasing energy production based on RES. According to the scenarios identified, the ones related to energetic plantations and energy production are viewed in Chapter 2.2.6.

Sales are calculated from selling fuel and energy at given **prices**. Current Producer Price Indexes have been used to have official prices (KSH), as well as electric energy statistics given mostly from 2004, the BFB retrofit project figures [OPET,2002a], data from the Hungarian Energy Office and Hungarian studies in this field. Based on these sources the per hectare plantation and per MW production values have been calculated, and multiplied by the plantation and production figures coming from other sub-models. The green electricity underwriting price taken for technologies independent from meteorology [GKM,2003], [GKM,2005]. Electricity produced from fossil fuels does not have this support, their prices were taken from various literature and project results [Bai,2005a], taken into consideration the price published by the Hungarian National Bank (MNB). There are wood produced and harvested in Borsod but since is not used in the local plants. The sales coming through selling them using average woodchips price represents the variable 'Sales fuel' in the model [Bai,2006b]. Revenue is calculated from summarizing sales and subsidies.

Gross margin is a further output variable, expressing the difference between total costs and revenue, as presented in Eq.11.

Gross Margin = Revenue - Cost of Goods Sold Eq.11

Value added refers to the contribution of the factors of production (i.e., land, labor, and capital goods) to raising the value of a product and corresponds to the incomes received by the owners of these factors. The factors of production provide services which raise the unit price of a product relative to the cost per unit of intermediate goods (e.g. raw materials) used up in the production. Value added is shared between the factors of production, giving rise to issues of distribution. It is calculated as Eq.12 shows:

Value added = Sales – Costs of Intermediate Goods Eq.12

6.5. Simulating the model

After the model is built with its sub-models and variables are defined with data and equations, the next working steps are verification, calibration, simulation and sensitivity analysis.

6.5.1. Verification and calibration of the model

After the model was structurally complete, it was checked for structural or logical errors. This verification was made for each component, checking errors in equations and units. Once errors were corrected, the calibration process was carried out. This is the model validation, based on comparing its simulation results to historical time series data collected from 1990 [Ventana Systems Inc.,2006]. Calibration was carried out through finding the variation of values of selected model constants that make the model generate those behavior curves fitting best the historical data. Input variables (calibration variables) of components selected for calibration (correction variables) were allowed to change within a certain range, thus achieving the best fit of correction variables to the historical one. To process the calibration of the Population sub-model, as example, calibration variables have been introduced, which might affect the birth and death rates. Those calibration variables are shown with green colors in Figure 88. The principle steps of the calibration of population sub-model are given in Figure 89. The first step of setting the calibration within the Vensim can be seen in Figure 89a, where Calibration has been selected, among optimization[13] possibilities. 'Population' is a calculated parameter (correction variable), whilst 'Calibrated Population' is a supplementary variable, containing given statistical data.

Choosing then calibration parameters (Figure 89b) and performing the calibration, the best combination of calibration variables is proposed according to the chosen integration techniques. A short report on the calibration is prepared by the model and the resulted corrected variable 'Population' can be viewed before and after this process (Figure 90). Within this example birth rate and death rate given by forecasts have been selected to possibly vary within +/- 5 %. As result, the optimized number of population has been slightly decreased in comparison to the BAU, so calculated values fit better to the forecasted ones (given by Hungarian statistics for the analized period). In this way calibration can be accepted and applied for further selected parts of the model, where appropriate constants are available.

[13] Optimization can be used to look for model errors, adjust model parameters based on data, test parametric sensitivity, and choose the best policy levers [Ventana Systems Inc., 2006].

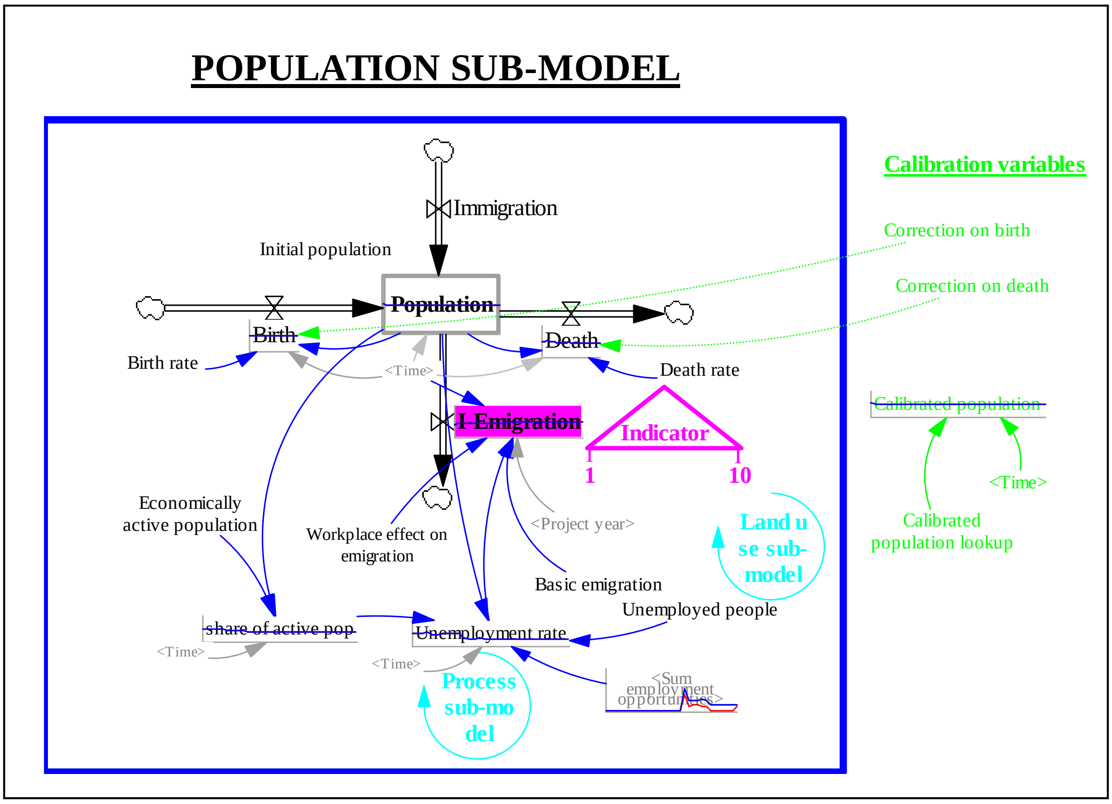
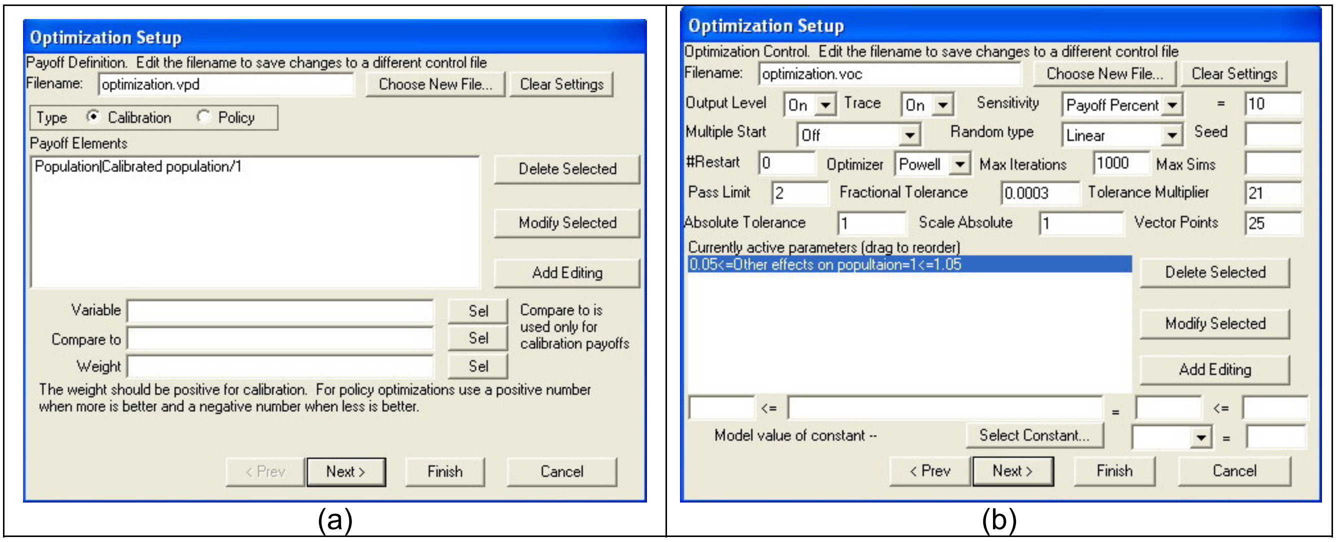


Figure 88: Population sub-model shown the calibration variables



(a) (b)

Figure 89. Example of calibration steps through 'Population' variable

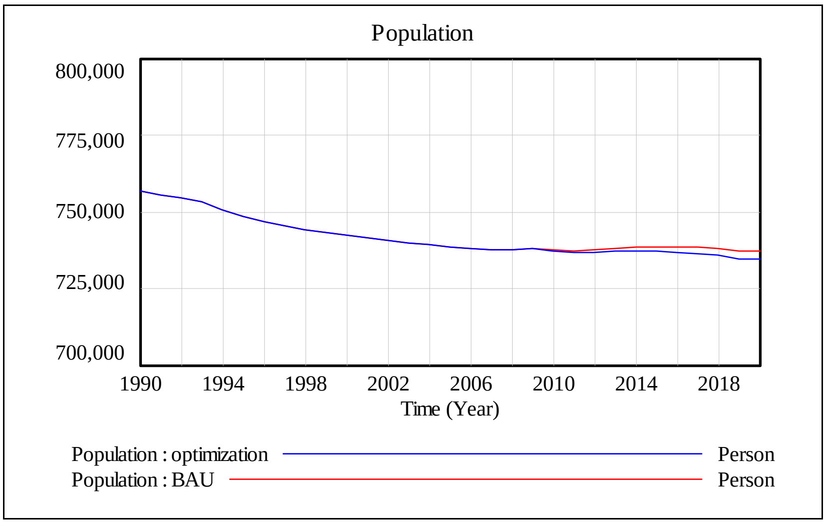


Figure 90: Results of calibration

Simulation of regional scenarios

After the model is built with its sub-models and data and functions are set and calibrated, it can be simulated. That means that its differential equations must be solved, for which integration must be processed, to advance the model in time. Integration is a mathematical process underlying simulation, applying a selected technique. The appropriate choice of an integration technique mostly depends on the modeling purpose. Some techniques, like for example Runge Kutta, RK 4 or RK 2 have the disadvantage of requiring several evaluations of the derivative. For most models of complex problems, with large number of aggregation, possible simplification, and lack of complete information, Euler integration is appropriate; therefore it has been used for the model simulation. The Euler method is a numerical procedure to integrate differential equations with a given initial value [Ventana Systems Inc.,2006].

The introduced scenarios - BAU, 'Retrofit' of a 30 MW boiler from coal to biomass and 'Straw fired plant' representing the establishment of a new plant – are then simulated within the model. All components of the scenarios can be set in the model via variables with hexagon form (see Chapter 6.3). In this manner, input variables change according to the selected scenario assumptions and the model can be simulated and analyzed, as presented below.

6.5.2. Simulation results of Population sub-model

Most important outputs of the Population sub-model are the number of population and emigration in Borsod over the examined time period (see Chapter 6.4.1). Simulating regional biomass scenarios results in additional workplaces for local people, which, in turn decrease the emigration of the area, presented in Figure 91. The indicator emigration for all three scenarios can be viewed for the simulation period. Among the two biomass scenarios there is no significant difference, as a similar amount of new employment can be ensured. Comparing both to the BAU, they contribute to the lowering of emigration. Historically the lowest emigration took place in Borsod in 1990 (i.e., within the analyzed time frame), which can be taken as the desired level in the future. After this year numerous industries have been closed, resulting in an increasing unemployment in the county, as main driver of the emigration.

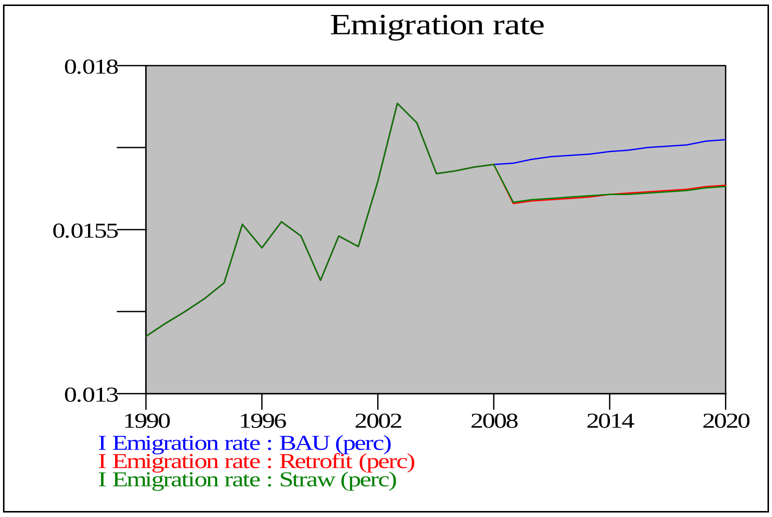


Figure 91: Simulation of indicator Emigration with all scenarios

Emigration influences the absolute number of population shown in Figure 92. According to the KSH, “population” consists of people living in one area with an officially registered address. Number of population reflects the people living in the area, working, paying taxes, investigating, buying materials, etc. It would be therefore desired to increase the population, but at least to stop its decreasing rate. Even though there is a limit to its increment, realistically the upper limit of the population size is not seen to be achieved, taking into consideration that Borsod has several communities with low population due to emigration or their aging. Increasing population increases the energy consumption, as included in the Energy balance sub-model. Besides, the production of waste, food and water consumption, social welfare, and numerous other effects resulting from population changes could be examined which, however, are not considered in this study. Establishing work possibilities for some hundreds by biomass projects is realistic, even though it could be analyzed in details through further social investigation. For example having a look to the possibly created jobs, they are available for “blue collar” workers, mostly for rural population. As in rural families the average number of children is higher than average one job for a worker might represent a bigger overall retention of people in the region. Analysis of such factors however should be included in a detailed separate social study.

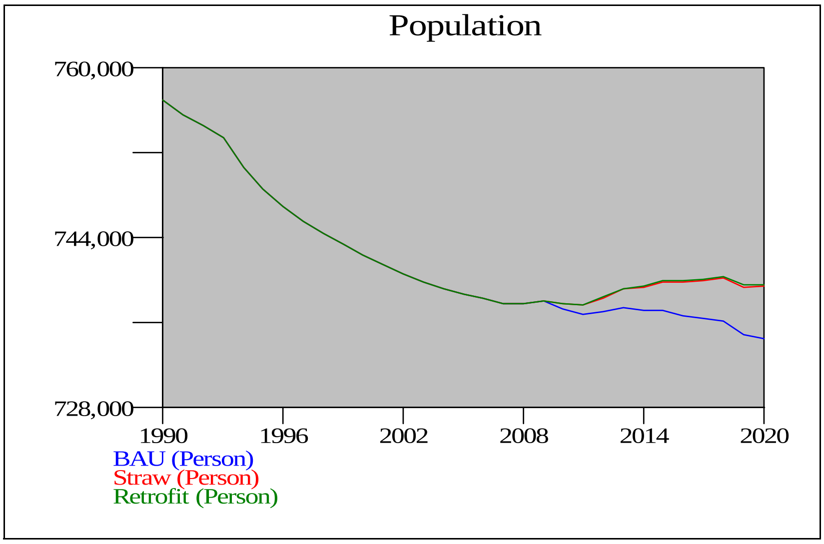


Figure 92: Population changes over the simulation in Vensim

6.5.3. *Simulation results of Land cover sub-model*

This sub-model simulates various land cover types, among which main output is the energy plantations coverage. Land cover is not of high significance in the Straw scenario, because it does not require changing the agricultural structure, integrating new products or taking various agricultural areas. Only few hectares (2.6 ha) are occupied for establishing the plant itself, and some infrastructure can be considered. When analyzing the conditions and effects of energetic wood plantations in the frame of the Retrofit scenario, several changes can be observed. The **energy plantation index** (Figure 93), referring to the change of energetic plantation areas in comparison to the total arable area, is increasing in the period of new plantations until 2013, as new products are introduced to agricultural production. Between 10-40 % of total arable land can be considered as appropriate for efficient and sustainable energetic plantations. Both, a smaller and higher share of plantation areas are not desired; the former clearly due to the unsustainable production, whilst the latter could cause monoculture agriculture. However, this aspect should be considered in conjunction with the energy demand, natural conditions and further factors. Along with the energy plantation, the level of **diversification** is enhanced as well, shown in Figure 93, which in general contributes to the development of a more "multicultural agriculture". Diversification level is calculated as a counter of various products. Therefore, following a linear correlation, the more crops are present in an area, the higher the diversification level (referring only to the crops with significant production). According to studies, half of the 260,000 ha of arable land in Borsod has unfavorable conditions, from which nearly 50,000 ha are covered with wheat and maize with high surplus production. In those areas energetic plantation could be established in Borsod, representing in this way a more sustainable and economic production.

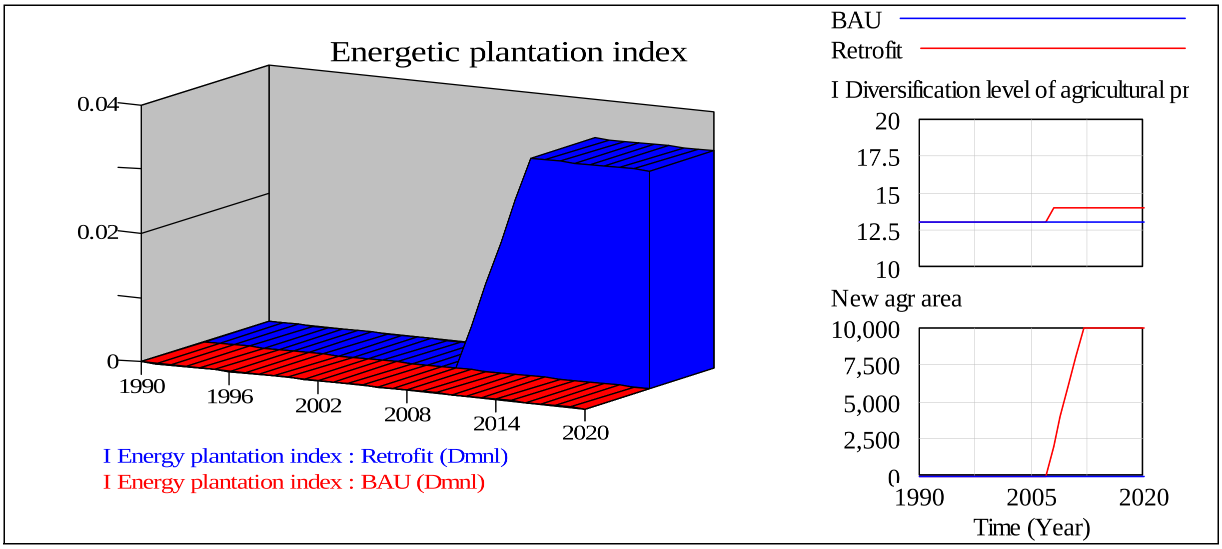


Figure 93: Energy plantation index and diversification level indicators in the Retrofit scenario

In the simulation of the Retrofit scenario the rate of **unsuitable area utilization** is growing, since plantations are to be established within areas with low quality land. Table 26 indicates reference values for BAU and Retrofit scenarios between the Project year (2008) and 2020. When applying Retrofit, a continuous increase can be observed until the year 2011 due to new plantations. The replantation of one fifth of existing arable land to energetic plantations can be defined as overall objective of Borsod.

Table 26: Indicator of Unsuitable area utilization rate when applying scenarios

Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
BAU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Retrofit	0.015	0.031	0.047	0.063	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079

As it can be seen, the establishment of one type of energetic wood plantation contributes to the diversification of agricultural production, which is an objective of the EU and Hungarian agricultural policies. It should be mentioned that the plantations are generally mixed, including more species, but within this study only poplar plantations are implemented.

6.5.4. Simulation results of Forest sub-model

Main output of the forest sub-model is its size, increment, logging and potential stock (in m³), as shown in Figure 94. No scenarios include the land cover change of forest areas, since they are predefined in forestry plans. Therefore they continuously increase for all three scenarios. However, in case the legal situation of energy forests will be established, the forests structure will be changed. An increased forest stock can be achieved, because there is a slight increment, being growth and plantations higher than logging (Figure 95).

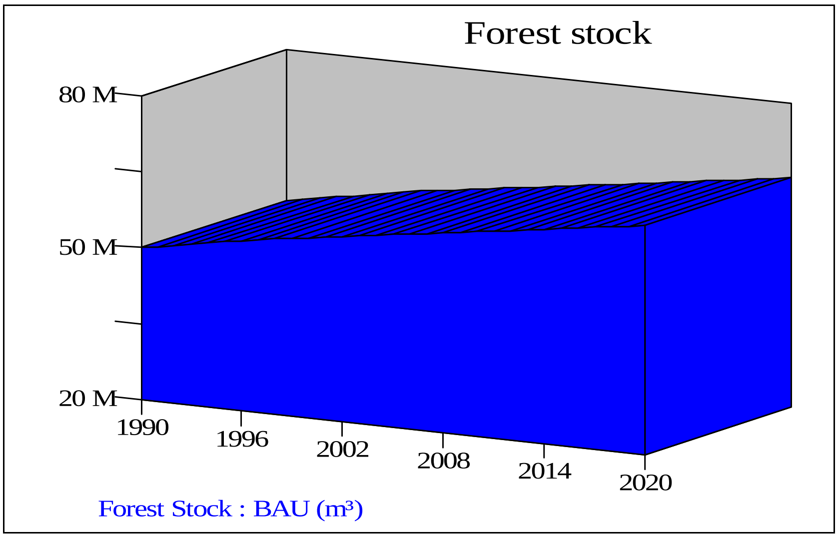


Figure 94: Forest stock (m³) in Borsod (BAU)

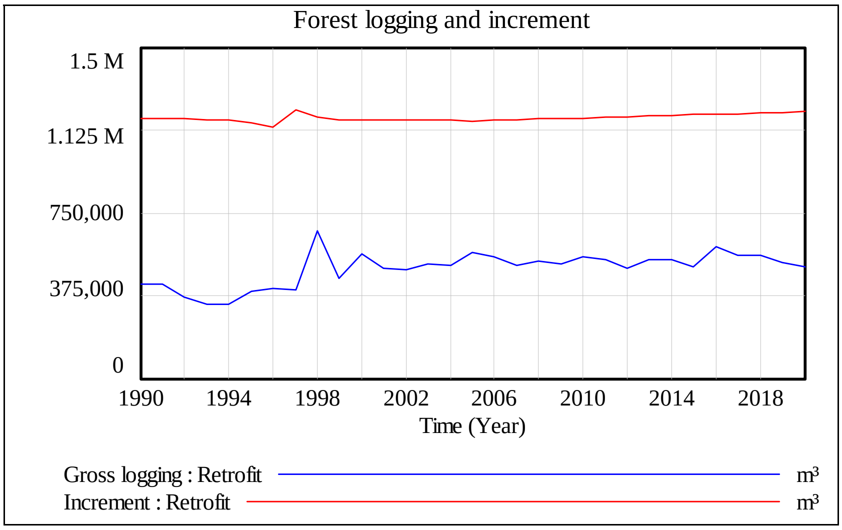


Figure 95: Factors influencing forest stock

Referring to the bioenergy systems, production of oxygen by biomass (forests and energetic woody plantations) is a positive factor. Having a look to the graph of Figure 96, it can be seen, when the whole plantations (10,000 ha) will be established, the simulation results in around 100,000 t additional oxygen production yearly. Other externalities resulting from forests are difficult to quantify, for example the recreation function, and the effects on biodiversity and on soil quality, among others.

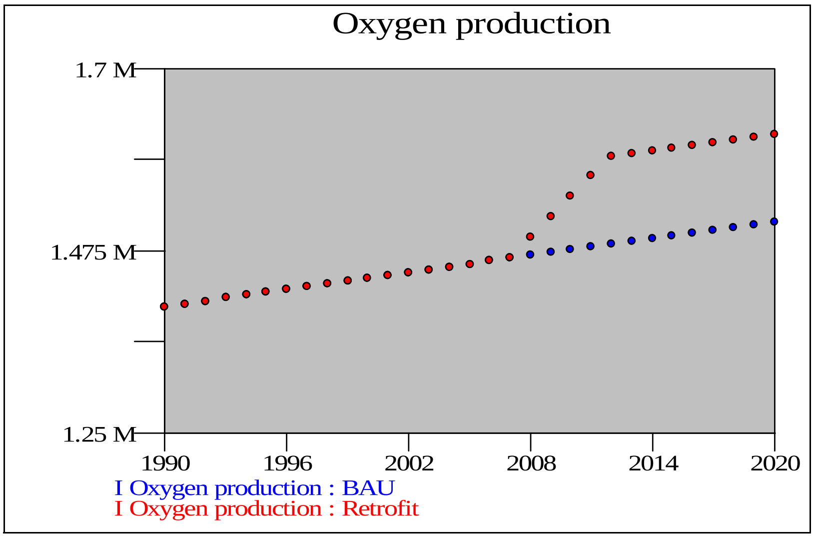


Figure 96: Oxygen production comparing BAU and Retrofit cases

Furthermore, there is an amount of forest biomass residues which are not yet collected, however presenting an economically feasible potential (according to the studies performed within this work). Besides, there is an amount which could be harvested according to the sustainable forestry plan. The total amount is shown in Figure 97, representing an amount of around 300,000 m³ wood yearly. This amount is close to the yearly fuel demand of a 30 MW_{el} capacity plant, and therefore it is an important aspect to consider in future technical and economic feasibility studies.

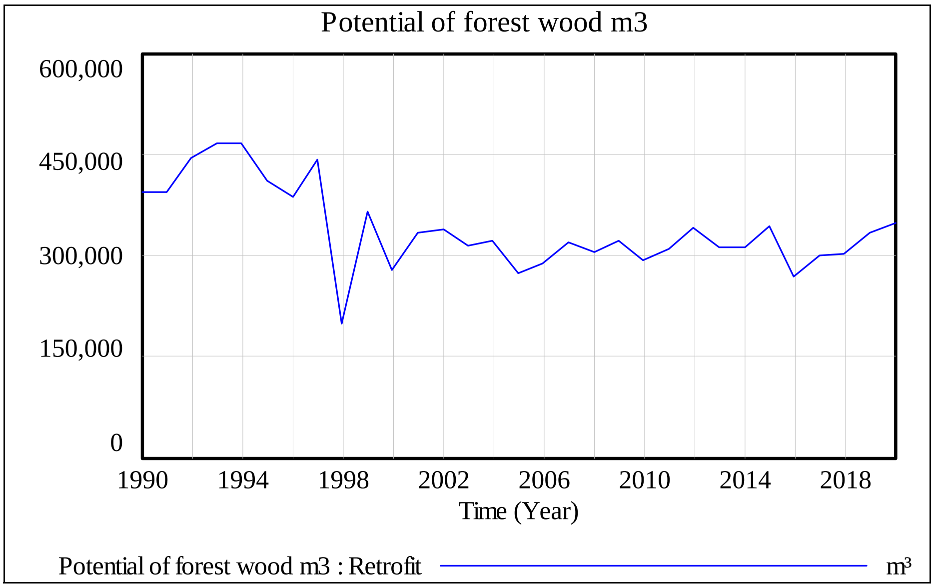


Figure 97: Forest wood potential for energetic purpose

6.5.5. Simulation results of Agriculture sub-model

Main outputs of the ‘agriculture sub-model’ are the crop production, overproduction and residues generation, as well as the animal stock and their residues. Since the crop products have been used as component of scenarios, related details were integrated in form of subscripts. However, the amount of crop residues available as energy resources depends on the number of animals, as since it is also used for their littering, which has been decreasing due to the falling number of animals.

In the future, no changes in the animal stock have been considered, nevertheless it is expected to decrease further, representing a higher amount of residues available for energetic use. Therefore the here presented results be considered as conservative, the real given situation could actually exceed these scenario results.

When considering that in BAU the agricultural production will be kept at the same level in the future as in the current year, still a high amount of **overproduction** of wheat and maize results form the simulation. This surplus production however is taken subjectively, which is defined according to the current policy, demand and supply conditions, and market situation of export products, among others; and of course not taking into account the global situation, in which the population of many countries does not have sufficient food. However, the identified overproduction can be abated through land use change towards energetic woody plantations, according to Figure 98[14]. The indicator, the rate of overproduction and production by crops is calculated after the simulation, outside of the model. Of course other possible ways for reducing overproduction could also be considered, for example the intervention on the prices, quota system, quantity limits, obligation for set-aside land, which could be implemented into the model. Consequently, when simulation the Straw scenario, the planned straw-fired plant will use the residues collected from agricultural fields, therefore it will slightly decrease over the years. This has been implemented into the model, and all byproducts sum up a new subscript type, namely the 'straw' within fuel types (Figure 99).

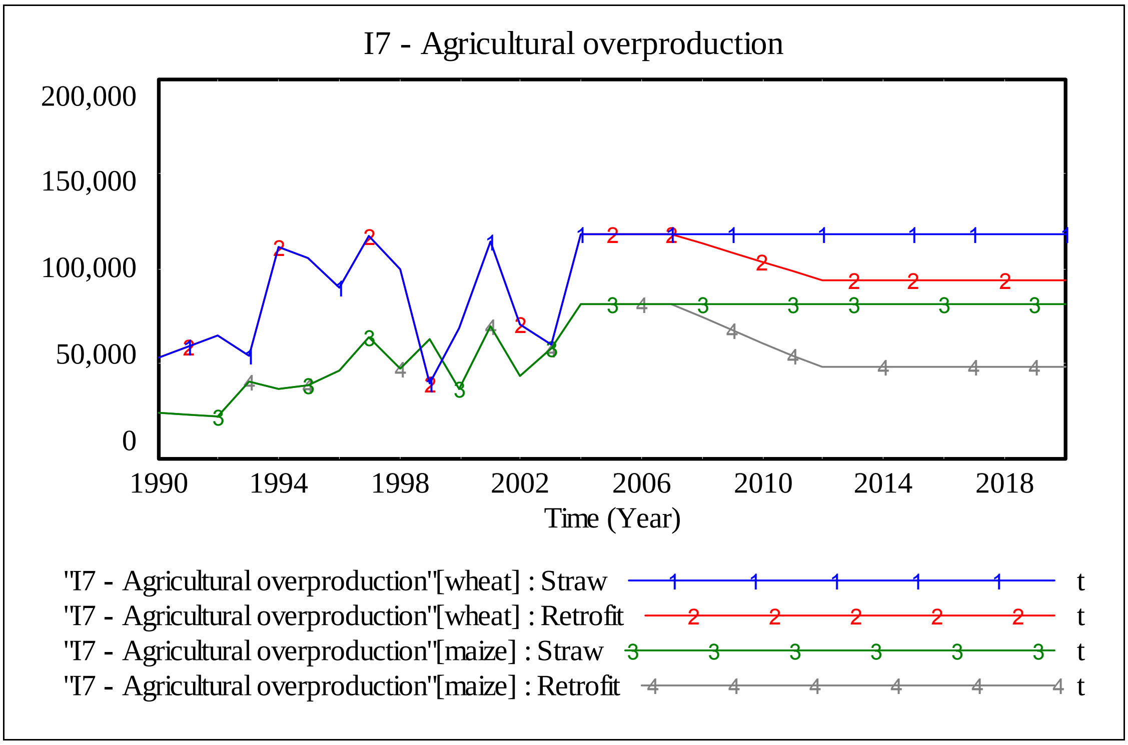


Figure 98: Overproduction of selected agricultural crops

[14] The name right after the indicator in square bracket refers to the subscript, while the name after the colon to the scenarios

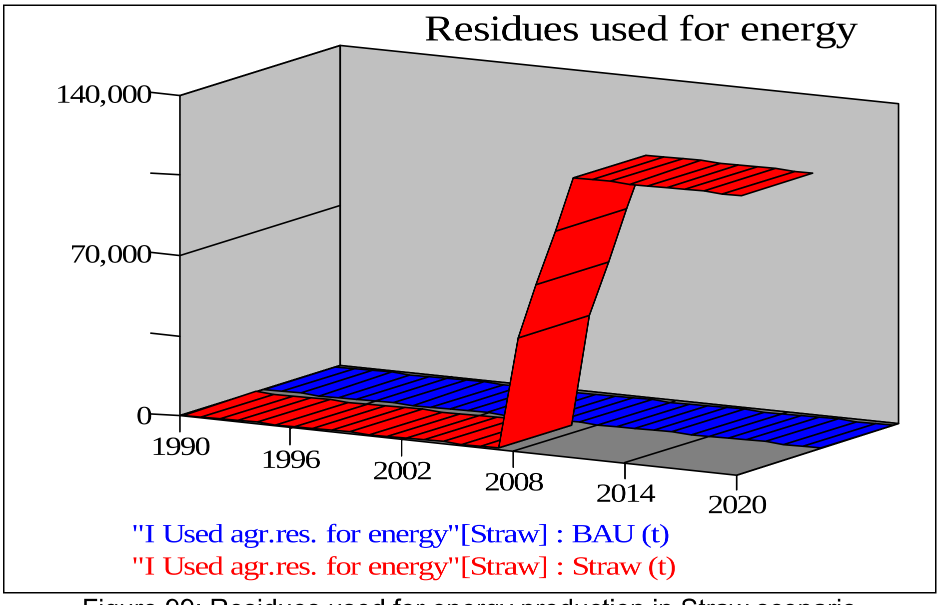


Figure 99: Residues used for energy production in Straw scenario

6.5.6. Simulation results of Energy balance sub-model

Most important results of this sub-model are the figures of fuel and energy production and energy consumption. Production of fossil fuels has played traditionally an important role in the energy sector in Borsod, in the form of coal extraction (Figure 100). Production of forest wood as source of fuel is slightly increasing, as well as the collection of straw, when applying the Straw scenario.

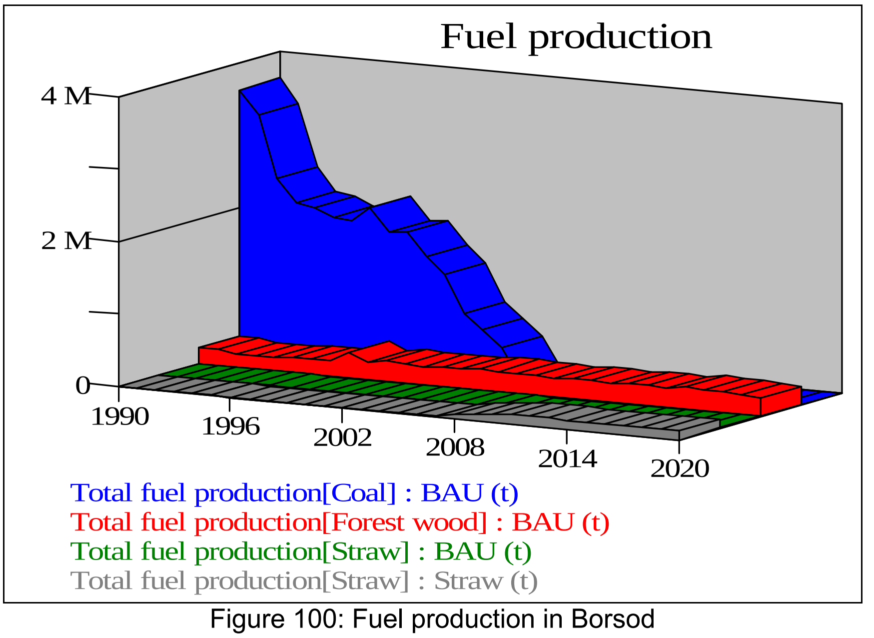


Figure 100: Fuel production in Borsod

The share of produced and imported fuels in plants is changing according to demand, supply and current policy. Figure 101 represents related capacities in case of realization of the Retrofit scenario.

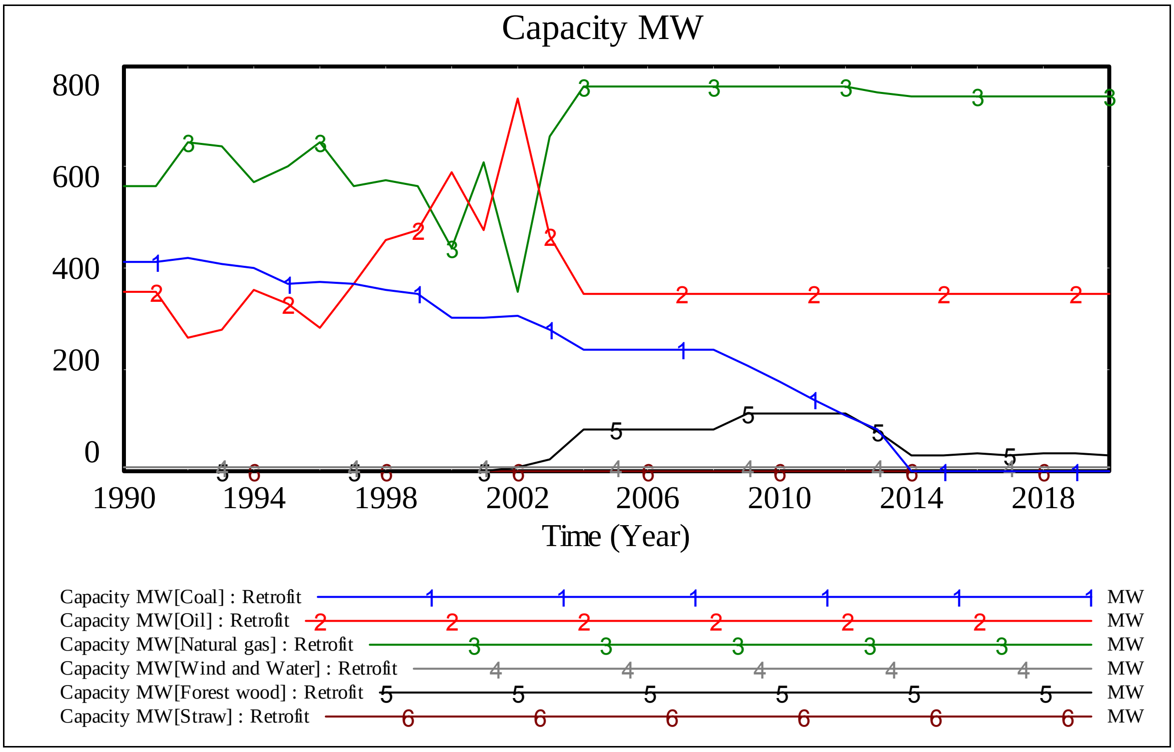


Figure 101: Capacity of plants in Borsod County (Retrofit scenario)

As it can be seen, current plants with coal are planned to close in 2013 and 2014 (line 1) whilst energy production based on gas has been increasing strongly after 2001 based on a large number of domiciliary connections. A high share of energy production based on oil can also be observed. Wind and hydro power production is still not significant; however there are new wind plants established. Use of forest wood started in 2002 and is expected to increase through using it within the planned energy station (Retrofit). However, the boiler is to be changed within the plant which will close up in 2014. This can be seen in the graph, that there will be a lack of around 300 MW capacity, which is a future task to be solved. It can be achieved in several ways, through enlarging life-span of the plants, or introducing other alternative solutions.

Fuels for plants, such as oil and gas need to be imported to supply the demand, as they are not extracted in Borsod. On the other hand, coal was exported until 2004 (Figure 102), due to its high extraction; after that year the mines closed, but still coal fired power plants are planned to operate until 2014. Coal must therefore be imported as well, implying higher costs and increasing dependency on energy imports. Therefore, more sustainable solutions must be investigated for the energy future in the county.

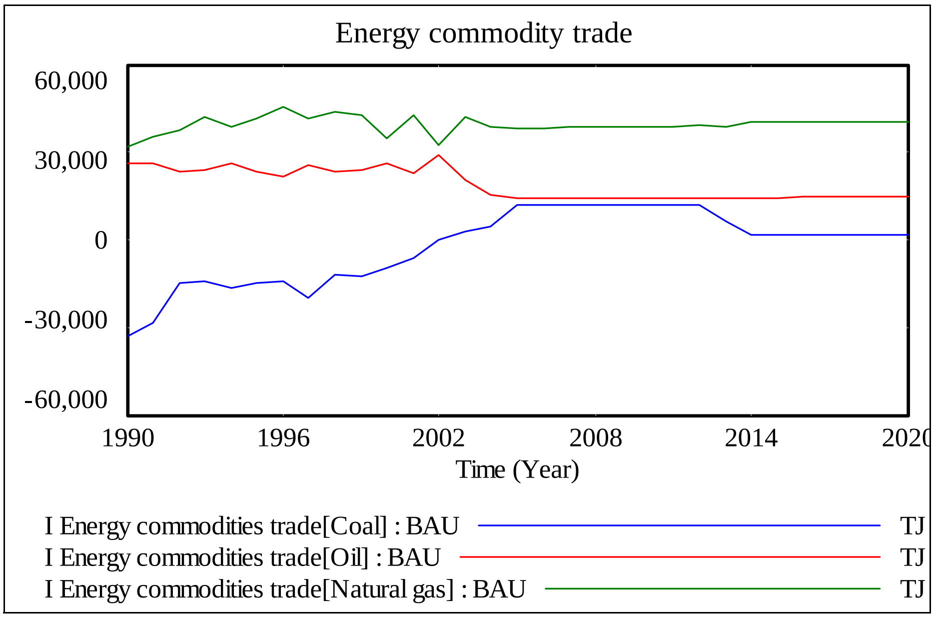


Figure 102: Energy commodity trade in BAU scenario

In relation to the total fuel commodity trade, a slight decline of their imports can be observed, due to the retrofit of even one boiler (Retrofit scenario) as shown in Figure 103. Regarding the straw as a fuel, it can be seen that further imports will be needed in the future: according to the potential analysis of this study, the technical potential of the county is around 1,500 TJ, whilst the straw-fired plant would need 4,500 TJ. Therefore, according to this current stage, import from outside of the county, but also export will be necessary. However, results of the theoretical potential analysis indicate an amount which could cover the whole demand of the plant. It would be possible to use this amount, if the structure of other sectors using the residues would change, such as the littering and feeding of animals, or if the technology or ways of gathering residues from small farms could be enhanced. The share of imported fuels is presented in Figure 104. Historically, in the nineties, 20-25 % was only the share of imported fuels, because there was still a significant coal mining activity within the county. This amount is theoretically achievable if the national policy, trade and other conditions provide a supportive framework for the increased exploitation of renewable energy production.

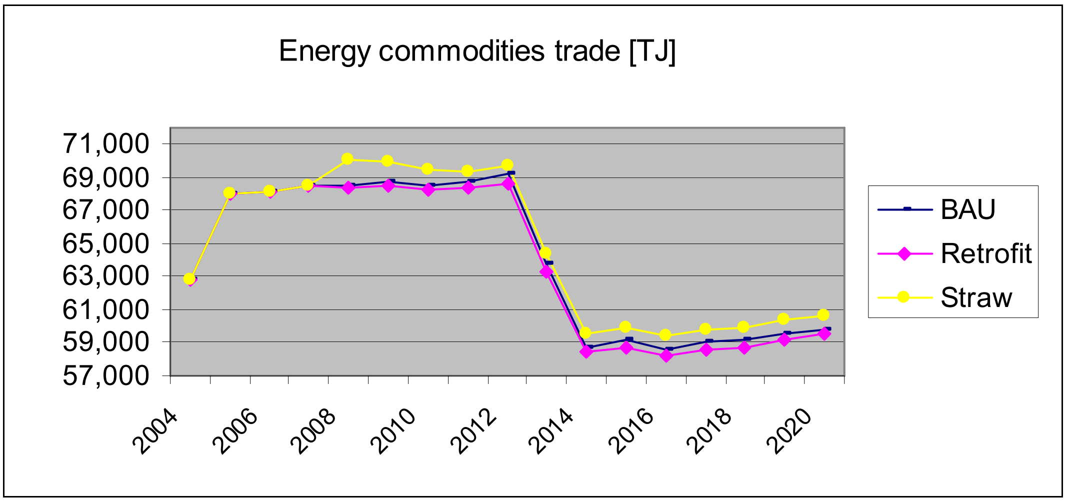


Figure 103: Import of energy commodities

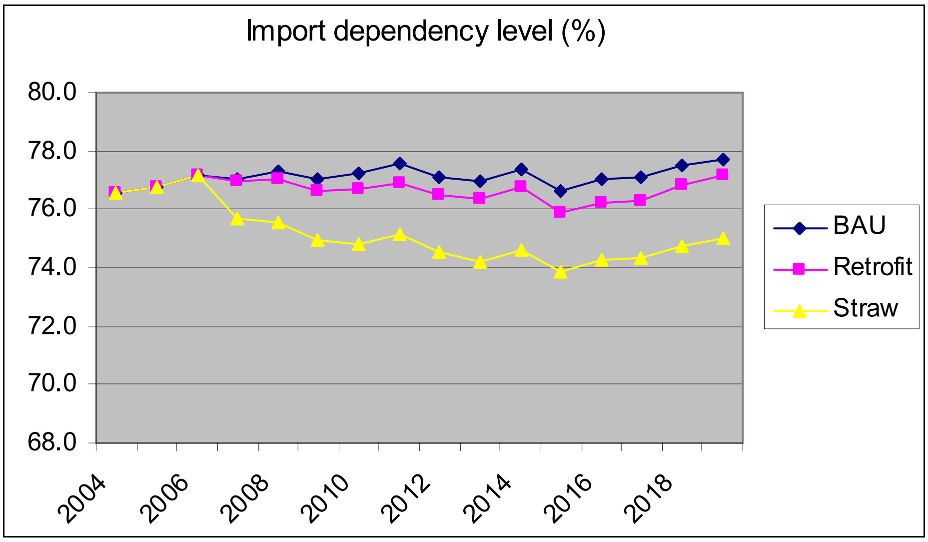


Figure 104: Share of imported fuels to the energy consumption by their types

With the established renewable scenarios especially electricity is being generated in Borsod, as shown in Figure 105a. The 'Renewable electricity indicator' is the proportion of electricity produced from renewables – including wind, water and biomass as well - in comparison to the total produced electricity. Historically, there was only a share of renewable electricity of around 1 % in Borsod, coming from the existing hydro power plants. This will be increasing even in the case of the BAU scenario, resulting from the installation of two wind turbines in 2004 (Bükkaranyos, 225 KW) and in 2006 (Felsözsolca, 1,800 kW), as well as the first retrofit of a coal boiler to biomass with 50 MW capacity in the year 2004, whilst hydro power plants continue to be operating. In the Straw scenario, the share of renewable electricity is the highest; the share of straw can reach such a high amount, because after 2014 significantly less electricity generation is being realized (due to the closure of the coal-fired power station), whilst straw-fired plant is supposed to operate for 25 years. The Retrofit scenario also offers an appropriate share of 12 %. Another indicator is the 'decentralization level', which is a dimensionless indicator, referring to the number of plants producing final energy in Borsod (Figure 105b).

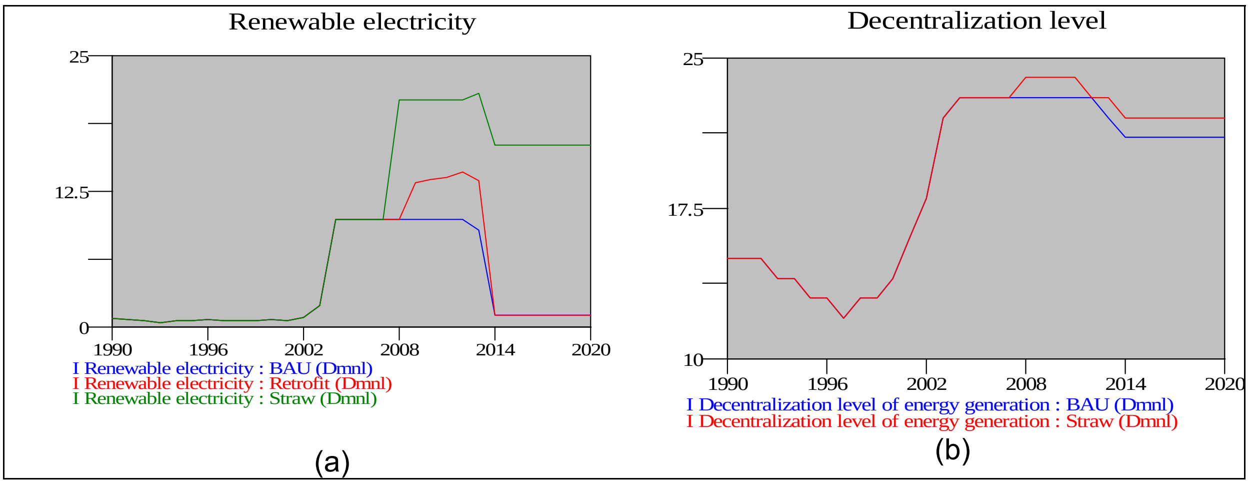


Figure 105: Indicators related to renewable electricity production

Energy consumption is calculated in two main ways: from the 'Energy production' part of the model for the consumption of the energy sector, while the 'final consumption' includes consumption of the agriculture, households, trade, industry and transport sectors. It must be noted that even though the plant capacities and their fuel demands are declining, energy demands from other sectors (households, traffic, industry, etc.) increase, and must be therefore supplied.

Analyzing in details the **sectoral energy consumption** was not the objective of the study; however, future figures have been estimated and calculated for each consumer sector by each fuel type. In a future within the BAU situation, Figure 106 shows the consumption patterns by fuel types, without the energy sector. As it can be seen in Figure 106a, the gas consumption continues to increase significantly in BAU scenario, as in the past, while use of firewood shows a decline in future. Coal follows the decline according to previous year's characteristics; oil is increasing slightly, due to the traffic sector's demand.

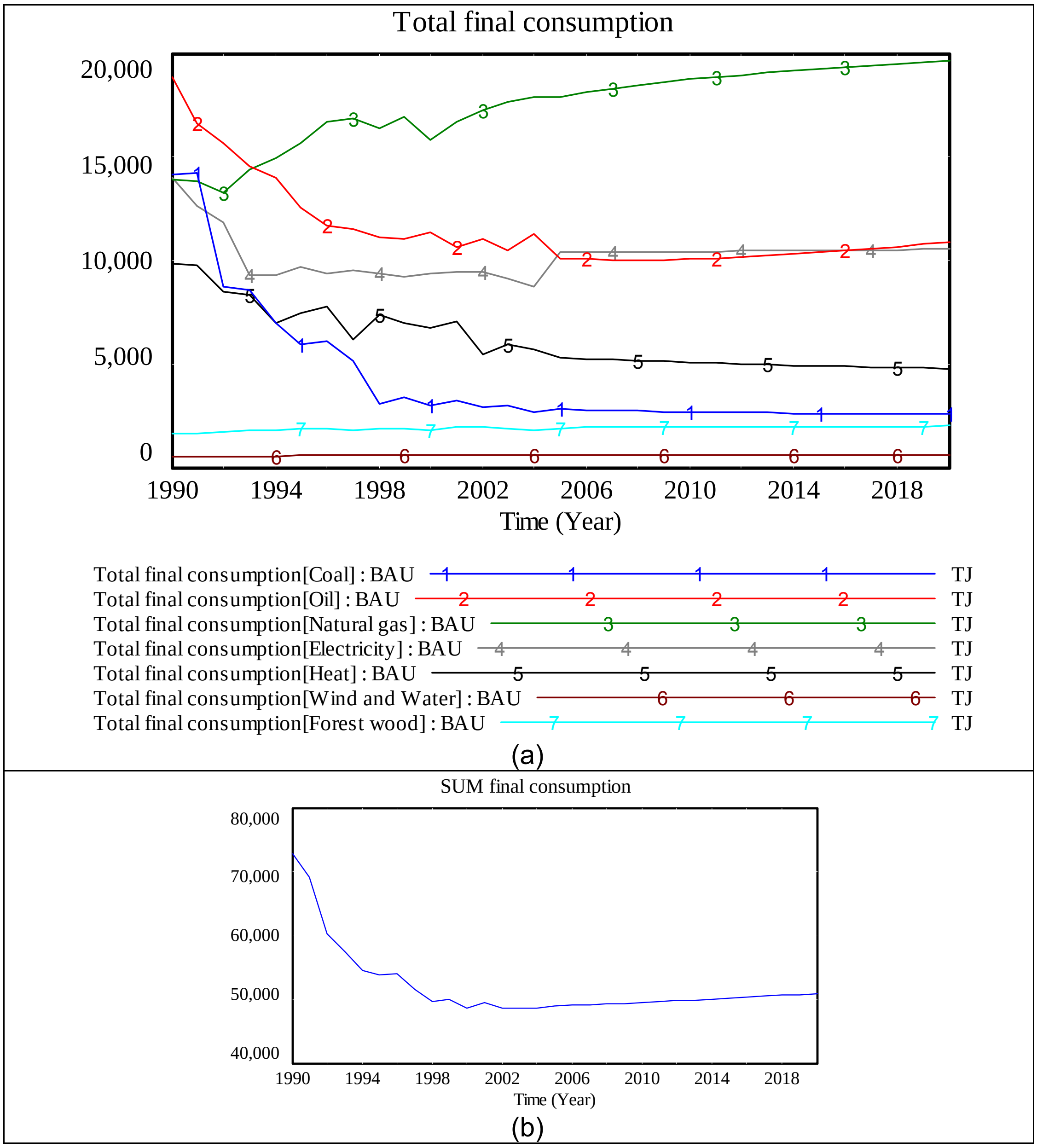


Figure 106: Final energy consumption in Borsod

Electricity and heat consumption do not show an increasing trend, especially because industrial production and number of population is declining in the future. However, it must be noted that the scenarios do not include the possible foreign and national investments into the industrial sector, which might change significantly the energy consumption patterns in Borsod. Adding the energy sector and final energy consumption results in the overall 'SUM final consumption' which is expected to slightly increase in the future in the time period analyzed (Figure 106b).

6.5.7. *Simulation results of Process sub-model*

The Process sub-model, as introduced in Chapter 6.4.6, simulates the production, extraction, transportation and conversion of the analyzed fossil and renewable fuels over the time. Another aspect of this sub-model is splitting of the effects on cost, employment and air pollution.

Employment

Through the representation of the biomass energy production chain, the possible employment at each step in the chain is represented in the model. The indicator 'Employment opportunities' represents the sum of the stepwise defined employment (in person) by fuel types. In case of the **Retrofit** scenario, there is an increasing number of employments in the fuel-forest-wood sector begining from the start-up year (Figure 107). It reaches 150 people employed, which returns to zero in 2014, when the plant closes. Besides, through the plantation of energetic biomass to supply the demand, about 60 people will be needed yearly for energetic wood plantations. Other employment opportunities are given if the **straw**-fired plant is built (Line 4 in Figure 107). Around 400 people are needed in this case during the plant construction, and 130 for the fuel transportation and conversion yearly.

Costs

Costs in case of the **Retrofit** scenario are implemented in details in the model, including the production costs, meaning establishment, cultivation and harvesting. In the first three years there is only the establishment cost, while from the fourth year, when cultivation will start-up, the costs increase. The following year the harvesting cost will be added, representing 3.4 million Euros yearly for the entire area. This corresponds to one fifth of the 10,000 ha, as it is supposed to harvest every year 2,000 ha, to supply the continuous demand of the plant. After 2011 all costs will occur, because while one part of the plantations is cultivated, another one is harvested or cultivated. The cost per fuel types for unit energy production is detailed in the description of Regional Economy sub-model.

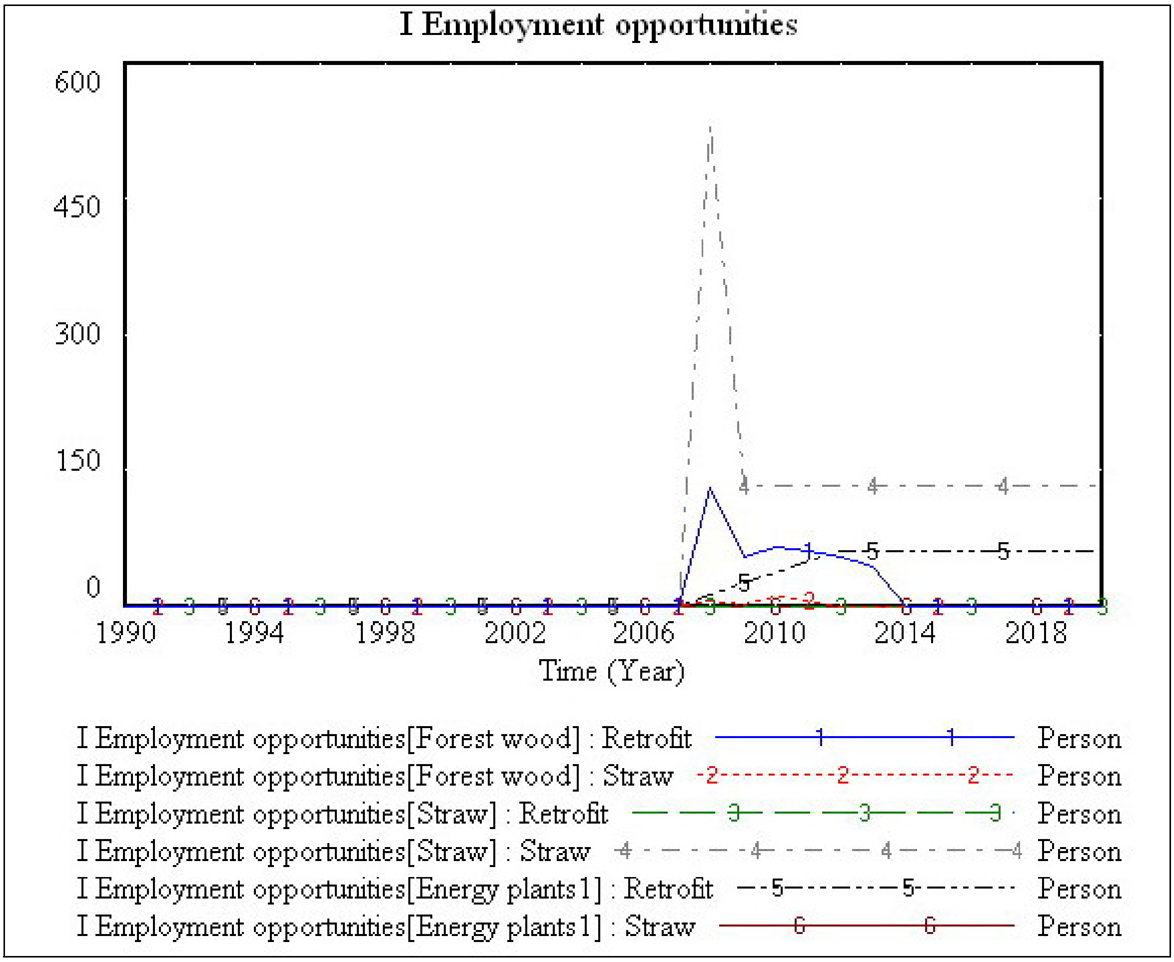


Figure 107: Employment opportunities when applying various scenarios in Borsod

Air pollution

Even though defining air pollution, its generation and decomposition by components is a complex task [Szarka,2007]. Within this study only the most important GHG, the carbon-dioxide (CO_2) is considered being one of the main motivation of using renewables. Implementing the unit emission of each step of the production chain, the total amount of CO_2 production is calculated for each scenario and fuel type. Figure 108 shows the changes over time when applying the BAU scenario. According to the simulation, pollution resulting from fossil gas and oil will remain in the future on the level of 2004, since no further changes are being considered. CO_2 pollution from energy production based on solid sources will decrease, due to the mentioned closure of power plants, and because using renewable fuels is considered to be CO_2 neutral in their conversion processes (see lines 5 and 6 of Figure 108). However a certain level of emission occurs from the machinery use during the collection and transport processes. Summarizing the emissions of each step of the energy production and consumption process, the Retrofit scenario contributes to a significant decrease of emissions, due to the conversion of a 30 MW coal-boiler to biomass boiler. This results in an emission decrease in the conversion, and even though emissions of other process steps are also included, the sum is still significant. On the other hand the Straw scenario causes a slight increase of CO_2 emissions, but it is only because the Straw-fired plant is planned to be built additionally within the region and not replacing fossil sources. In this way, of course there is higher emission, as comparing to the state of no new installations for energy production. A more representative comparison could be achieved when analyzing these emissions with the ones resulting from the operation of fossil power plants with the same capacity. Therefore, the CO_2 emission for each generated TJ has been calculated using model simulations, which result in 95,000 kg CO_2/TJ when using coal, 1,700 kg CO_2/TJ in the case of straw and 2,500 kg CO2/TJ when using forest wood.

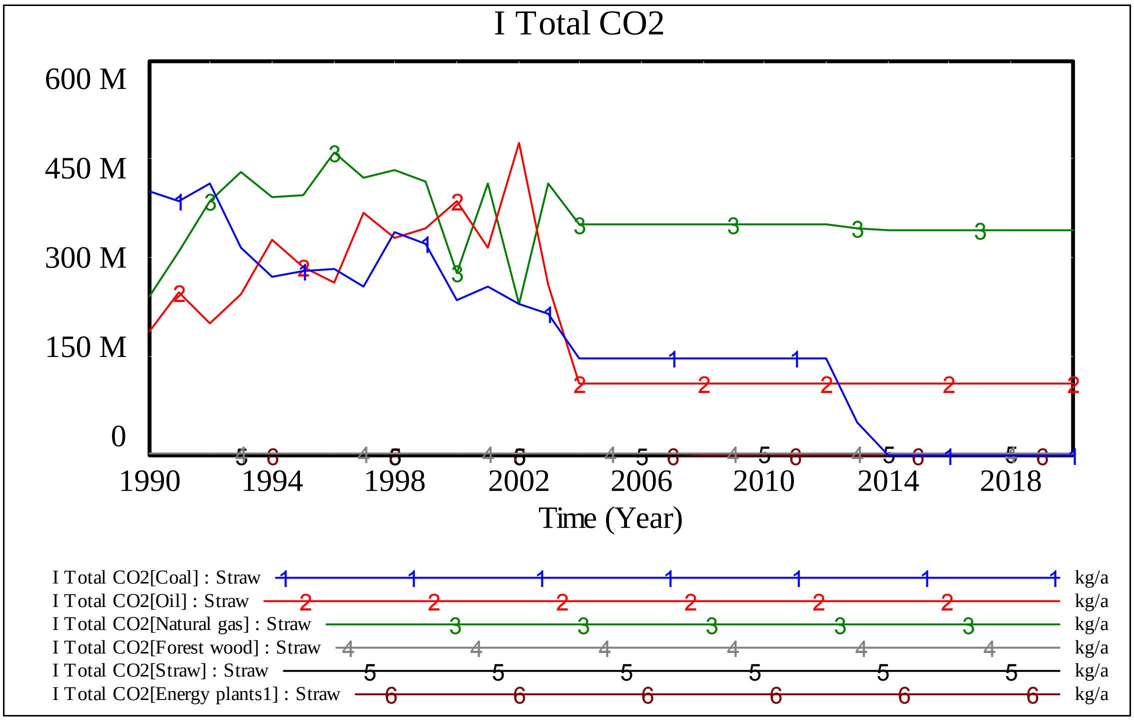


Figure 108: CO2 generation by fuel types in Straw scenario

6.5.8. Simulation results of Regional economy sub-model

Main outputs of this sub-model, as introduced before, are the costs, value added and gross margin. Subsidies are also detailed; the ones related to the **Retrofit scenario** are shown in Figure 109. As it can be seen in the graph, there is a support of EUR 1.8 million - 20% of the investment - at the year of its establishment, which is financed by the Dutch Government due to a Joint Implementation Agreement [OPET,2002a]. Besides, support is given for the establishment of energetic plantations in the frame of the Single Area Payment Scheme (SAPS), which is 190 EUR/ha for short rotation coppice (less than 5 years) according to the [FVM,2005]. Further support will be available (10.94-85.9 EUR/ha) for utilization of unsuitable areas, which is implemented into the model. Summarizing those, more than 2.5 million EUR can be taken yearly for the planned 10,000 ha plantations. In case of the **Straw scenario** support is given for the establishment of the straw-fired plant, which is maximum 40% of the investment (EUR 122 million) according to actual Environmental Infrastructure Operative Program (EIOP).

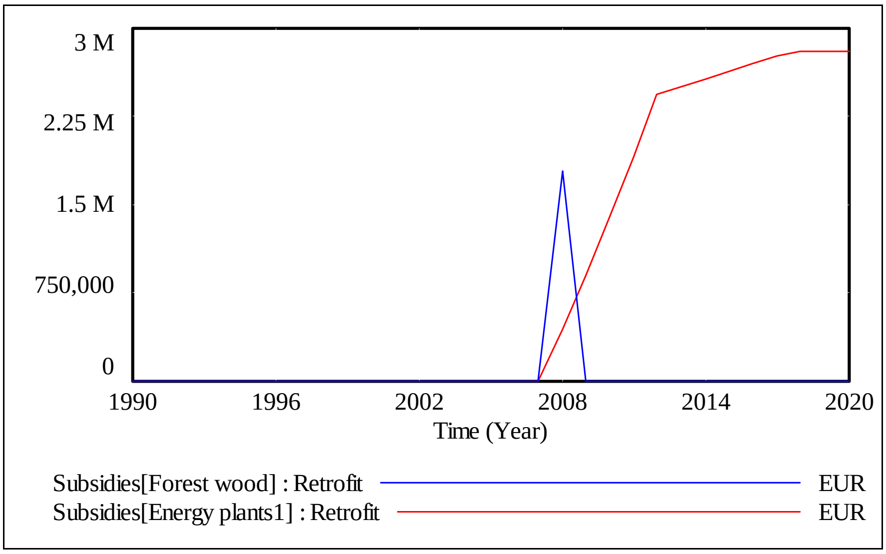


Figure 109: Subsidies of wood and energy plantations in case of Retrofit scenario

Further component of the economy sector implemented into the model is the sale resulting from energetic woody plantations, after what the plant will close up. The sum of sales and subsidies gives the revenue, shown in Figure 110. Revenue from generating energy based on forest wood is increasing when comparing to BAU, as well as that based on straw (Straw scenario). It is due to the underwriting price of green electricity higher than market price, but also the subsidies for construction and energetic plantations are included.

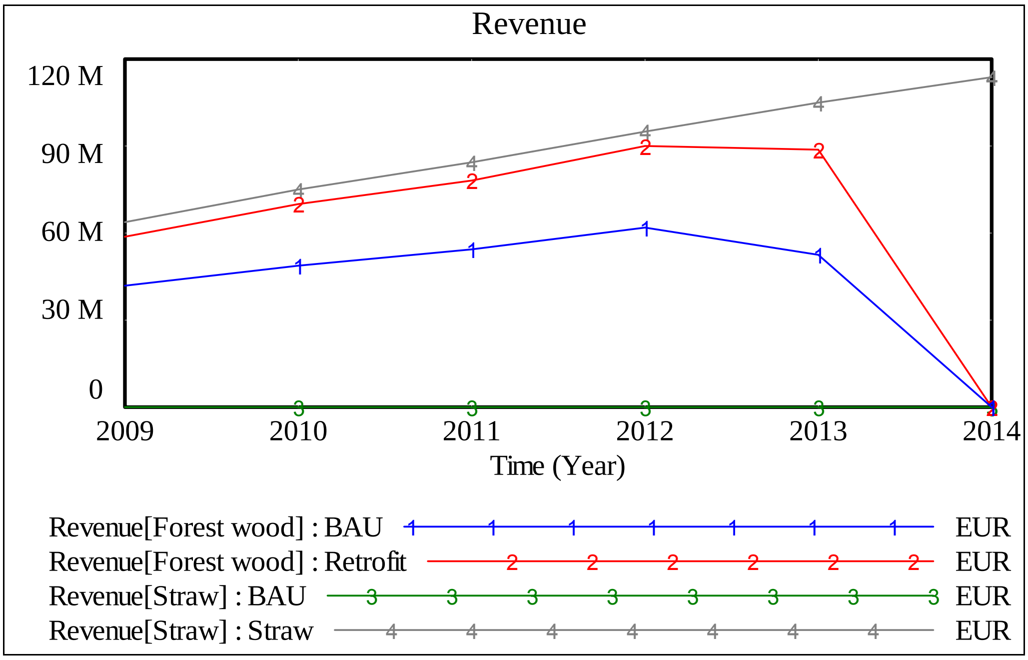


Figure 110: Revenue represented by selling energy based on forest wood and straw (BAU and Retrofit scenario case)

Besides revenue, there are costs related to energy generation, calculated in the Process sub-model. Results, unit costs of one TJ energy production, are shown in Figure 111. When analyzing the period 2002 to 2014 it can be seen, that yearly costs of energy production based on fossil fuels are still under the unit costs of that of biomass. As a fraction of the costs based on biomass, energy production based on oil is 80%, based on coal is 50% whilst based on gas is 30%. However, a reason could be, that no further investment for technologies based on fossils have been considered. Besides, gas and oil prices might increase with a higher rate as presented and the know-how and technology transfer as well as the learning-by-doing effect will further decrease costs of renewables.

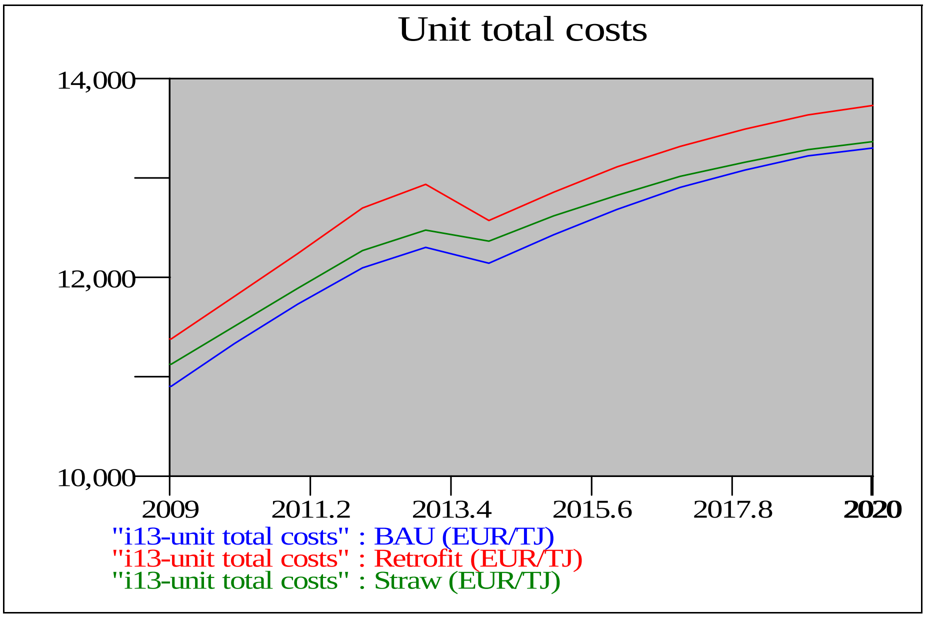


Figure 111: Total costs of specific energy generation (all scenarios)

Figure 112 shows the difference of revenue and total costs referring to 1 TJ energy production, represented by the gross margin. In case of forest wood it can only be analyzed until the plant closes in the year 2014. However, there is still income after that year, because energetic plantations can be sold. As the graph shows, only the natural gas-based energy production has a higher gross margin, and both coal and oil use represents lower values when comparing to forest wood in the Retrofit case. Value added is presented in Figure 113 for applying Straw scenario, comparing to BAU scenario.

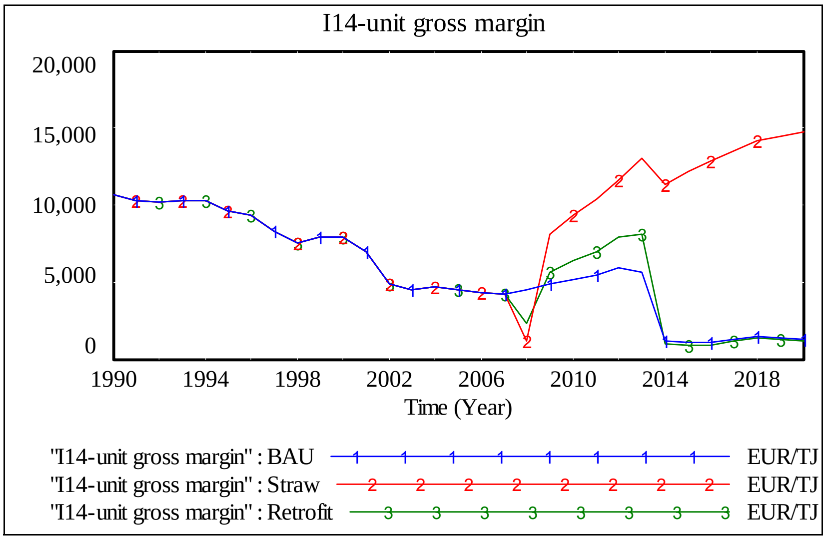


Figure 112: Gross margin for the generation of one TJ energy for each scenario

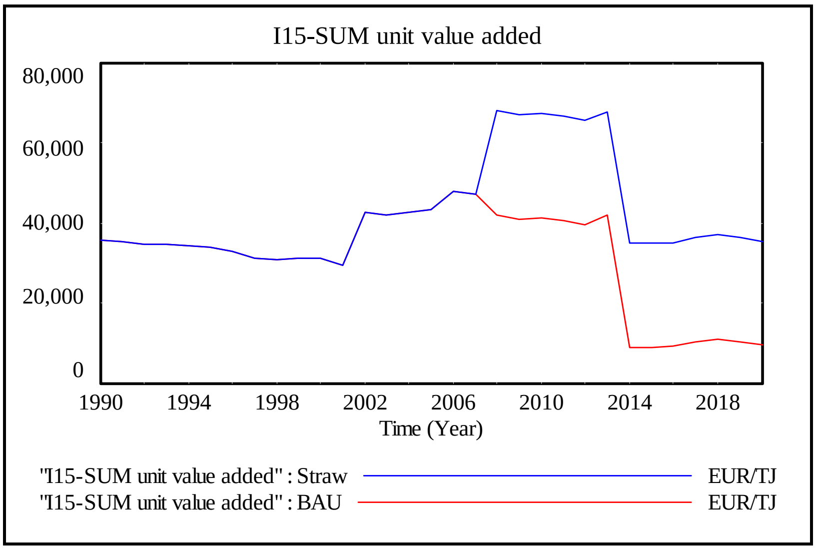


Figure 113: Value added for the generation of one TJ energy in Straw and BAU scenarios

Analyzing the results proves, that in case of further maintaining the current energy systems and manners (BAU), it will have several negative impacts on the region both in short term and long term (until 2020). When applying the “Retrofit” scenario, an enhancement is observed on the regional development through establishment of new workplaces, and an even so decrease of the constant emigration of the county. Further positive impacts are the mitigation of CO_2 gas emissions and the dependency on fuel import. It also supports the diversification of agricultural products with the introduction of a new crop. However, it does not contribute to the decrease of overproduction, as the scenario straw-fired plant does. Besides, this third scenario has a relatively high investment cost in comparison to the second one, but also contributes to the renewable electricity production with a higher share, so also to the decrease of the decentralization level and fuel import, supporting so the development of a more sustainable region. When completing the 10,000 ha of plantation, it is expected to decrease the soil erosion with about half million tons and with 75,000 t the deflation, according to studies of [Bai,1999].

6.5.9. *Sensitivity analysis*

Data sources used to fill the model equations have been different databases, personal information, statistics and literature. In several cases there are not regional data available, or not for a long historical period. In other cases, more data sources have been used to collect and process quantitative model variables or simple a range of values are given for a variable. All these result in the insecurity of several values, therefore a sensitivity analysis for selected key variables have been carried out. As an example, Table 27 summarizes selected values gathered for the calculation of agricultural residues. As it can be seen, a significant range of data is available. For setting this sensitivity, **Monte Carlo** multivariate sensitivity has been performed. The Monte Carlo simulation works by random sampling. To perform one multivariate test, the distribution for each parameter specified is sampled, and the resulting values are stored and used in a simulation. Multivariate represents causes in all constants to be changed together. The number of simulations is set at 200, which means that this process will be repeated 200 times. **Noise seed** allows specifying the seed to be used in computing the random numbers for the sensitivity analysis.

Table 27: Given data ranges summarized for agricultural residues

			Crop types						
Name		**Unit**	**Grain**	**Maize/Corn**	**Sunflower**	**Rape**	**Grass**	**Fruit**	**Grape**
Name of area			Arable	Arable	Arable	Arable	Grassland, Pasture	Orchard	Vineyard
Size of area in 2004 (KSH)		ha	112,981	34,456	38,102	16,945	121,647	7,218	8,697
Name of residues			Straw (bales)	Corn-stalk	Sunflower-stalk	Rape-straw	Grass	Loppings	Grape-cane
Yield of product in 2004 (KSH)		t/ha/a	4.629	6.74	2.35	3.05	1-10		6.7
Product-byproduct ratio	Total res.		1:0.9 - 1:1.4	1.8	2.00	2.9			
	Harvestable res.		1:0.9 - 1:1.4	1		1.7			
Yield of total residues 2004	Fresh mass	t/ha/a	3.8	12.1	4.7	8.8	20-35	2.5	1.8
	Air-dry mass	t/ha/a							
	Water c.not given	t/ha/a							
	By 15% w.c.	t/ha/a				3.5			
	Atro	t/ha/a					1-7.3		
	Atro	t/ha/a	3.2	5.8	3.2	4.2	1.4		
Total residues	Fresh mass	t/ha/a	430,721	418,020	179,079	149,879		18,045	15,655
Harvestable share of res.		%	90-100	50-80	45-55	50-80	20-35	40-50	40-50
Comment:	*estimated/calculated*								

In order to do sensitivity simulations the type of **probability distribution** values for each parameter must be drawn. Within this work mostly random uniform distribution, normal distribution and random triangular has been applied [Ventana Systems Inc.,2006]. Setting of the selected variables (harvested residues) is shown in Figure 114.

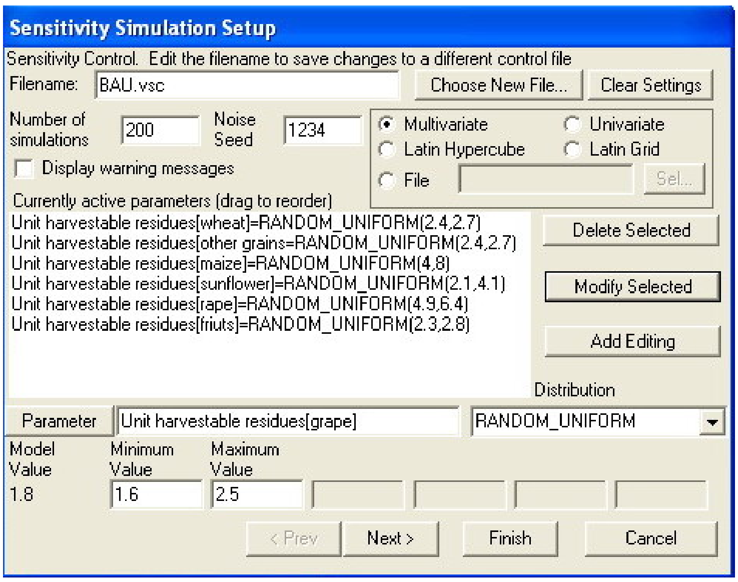


Figure 114: Setup of sensitivity simulation for variable 'Unit harvestable residue'

As results, residues for selected wheat, maize and other grains can be viewed over time Figure 115, and the variable 'SUM residues for energetic purpose' calculated based on the unit residues is presented in Figure 116.

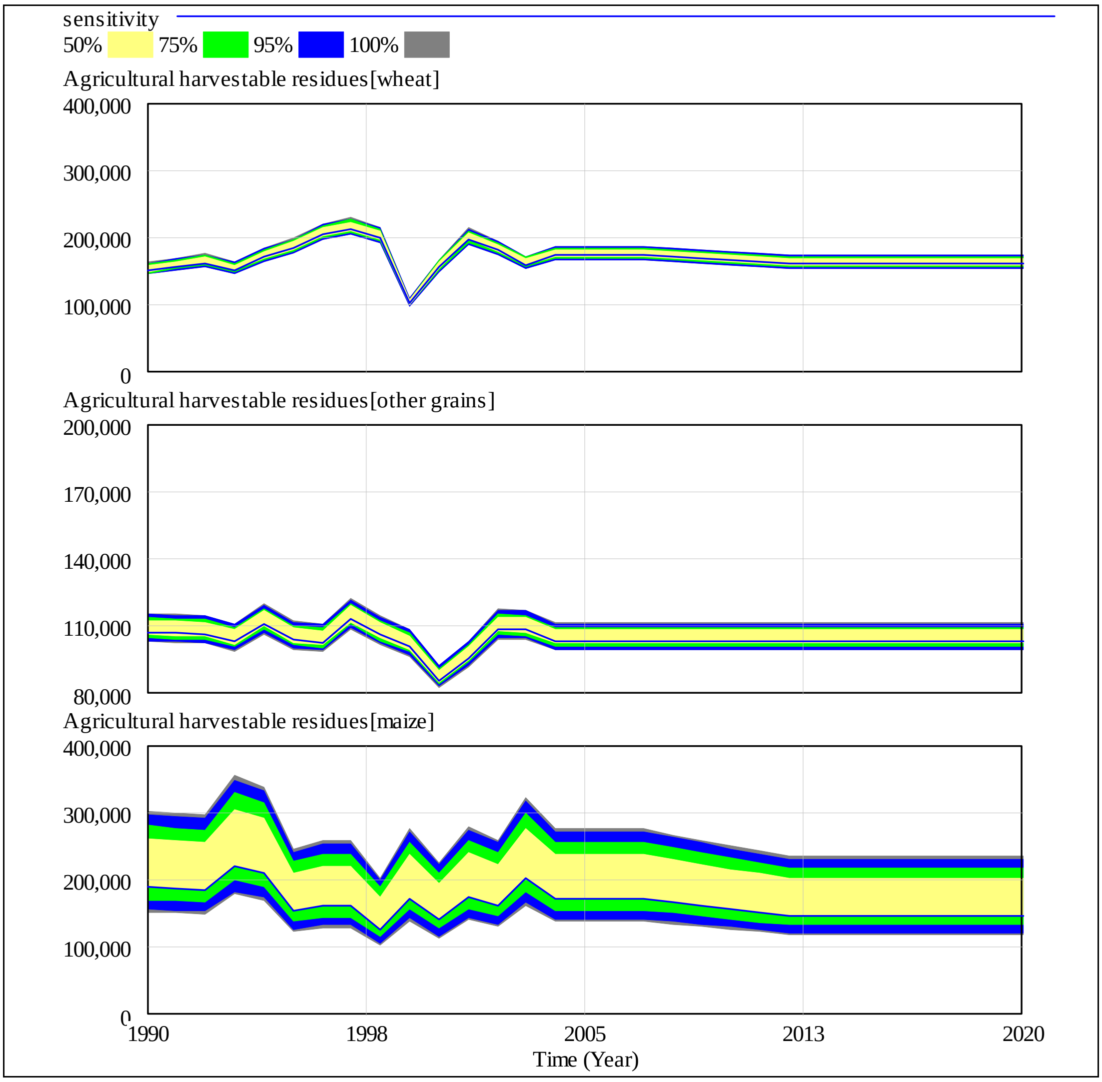


Figure 115: Sensitivity graph of selected crops amount (t)

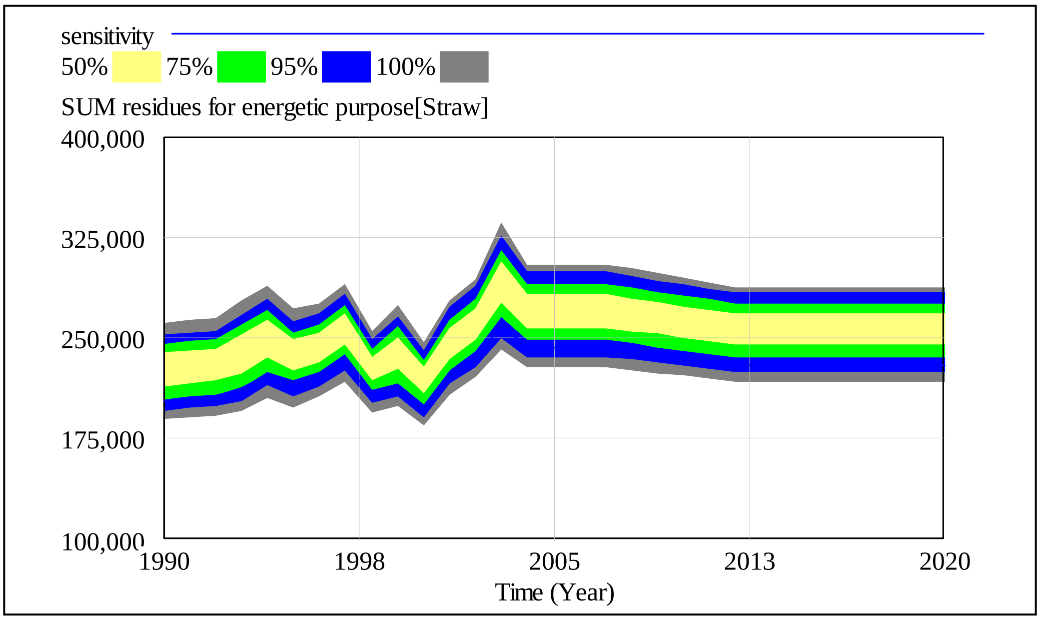


Figure 116: Sensitivity analysis of 'SUM residues for energetic purpose' variable

7. Achievements towards sustainable regional development

7.1. Indicators of sustainable development

As introduced in Chapter 5.5.1., each indicator was defined with its name, unit of measurement and a short description about them was given. Afterwards their utility functions were defined uniquely following Gossens's First Law about decreasing margin of utility, among others. Through simulating the biomass scenarios in the system dynamics model (see previous Chapter), the changes of indicators in time can be observed. Those changes can be seen and analyzed in any selected point in time. The reference years of 2004, 2010, 2015 and 2020 were selected to present and compare results. Numerical values of indicators from these years were exported from the model into the objective system, where their scores were calculated by applying their utility functions. All indicators record a value (score) between 1 and 10, therefore they can easily be compared. Scores of selected indicators are presented in this chapter and a more complex representation is included in Annex XVIII. It must be noted, that relative changes among scenarios should be seen for a more reliable comparison.

7.1.1. Economic indicators

Economical development of Borsod was evaluated as the objective with the highest importance, both at macro and micro level. Key indicators identified at **macro level** are coming from the agriculture and energy sectors. The indicator Unsuitable area utilization rate shows the rate at which low quality areas in Borsod will be utilized in the future, according to the scenarios. The simulation results presented in Figure 117a show that both BAU and Straw will not contribute to the increase of this rate, because establishment of new agricultural products is low quality areas is not foreseen. But Retrofit scenario shows its significant development, achieving a score 4 in 2010 and 6 in 2015. The reason is that the boilers retrofit from coal to biomass requires increasing amount of woody biomass, which cannot be covered with traditional forests increment, therefore the establishment of poplar SRC plantations will take place in areas on low quality land. Historically wheat and maize fields were established in those areas, but they face the difficulties of surplus production due to changes in the market circumstances and decreasing demand for them. Planting poplar does therefore contribute to the growth of low quality land utilization, and representing a new and marketable product, which is supported by the EU, an economic development is stimulated.

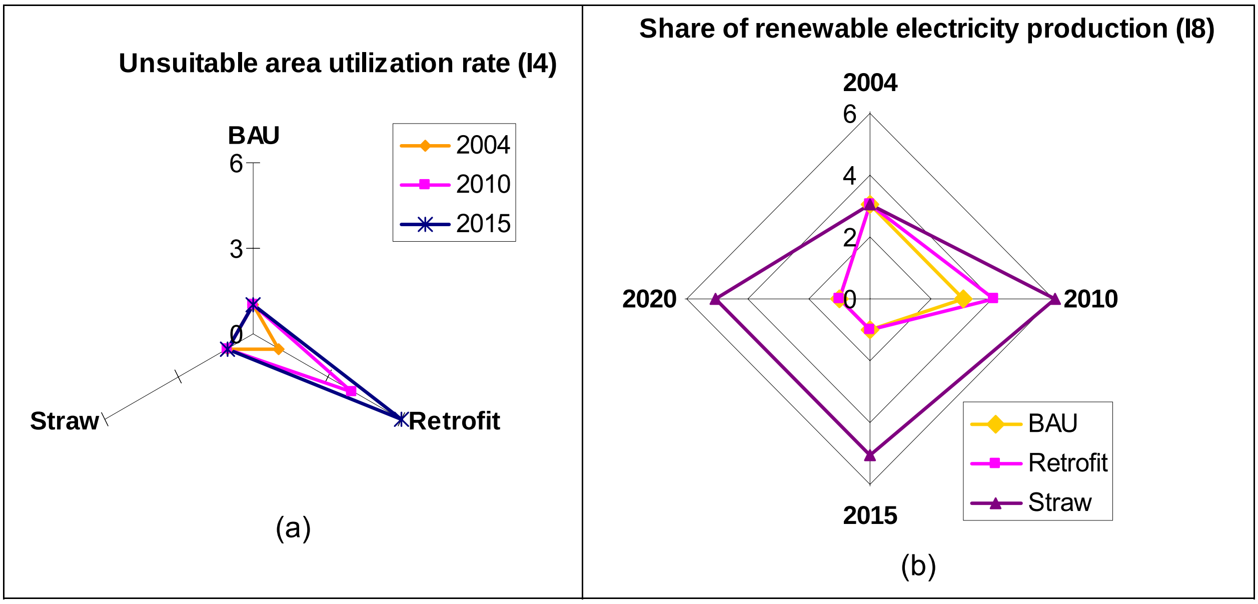


Figure 117: Scores of economic indicators until 2015

Another indicator is the Agricultural surplus production, which is improves the most in Retrofit case, and presented in Annex XVIII along with further indicators. By performing the retrofit described and establishing straw-fired plant clearly the electricity generation from biomass sources will increase, which is a goal at regional, national and even at European level. In Figure 117b the renewable electricity can be seen for scenarios, from which clearly Straw proves to be the most effective in mid and longer term as well. Retrofit shows an increasing trend, but after 2014 does not contribute anymore to green electricity production, because plants will close up. This aspect must be taken into consideration in case of any interpretations after the year 2014.

The import level of the county on fossil fuels has been worsened; the alleviation of such dependency is defined as regional objective matching also them at national level. This is perceived by the indicator Energy dependency level, the scores of which are shown in Figure 118a. Scenarios take the maximum score 6 out of 10, which is reached in current year (2004). This dependency level is increasing further if BAU will take place, since the last mines in Borsod closed in the year 2004; therefore (except few lignite and renewables) all fuels must be transported out of the region or even imported. Establishing the straw fired plant will reach the score 4 in 2005 and will keep it after, since the plant will operate within the analyzed period. Retrofit has a better score than BAU in 2010 (3), but afterwards will be the same (closure of plants).

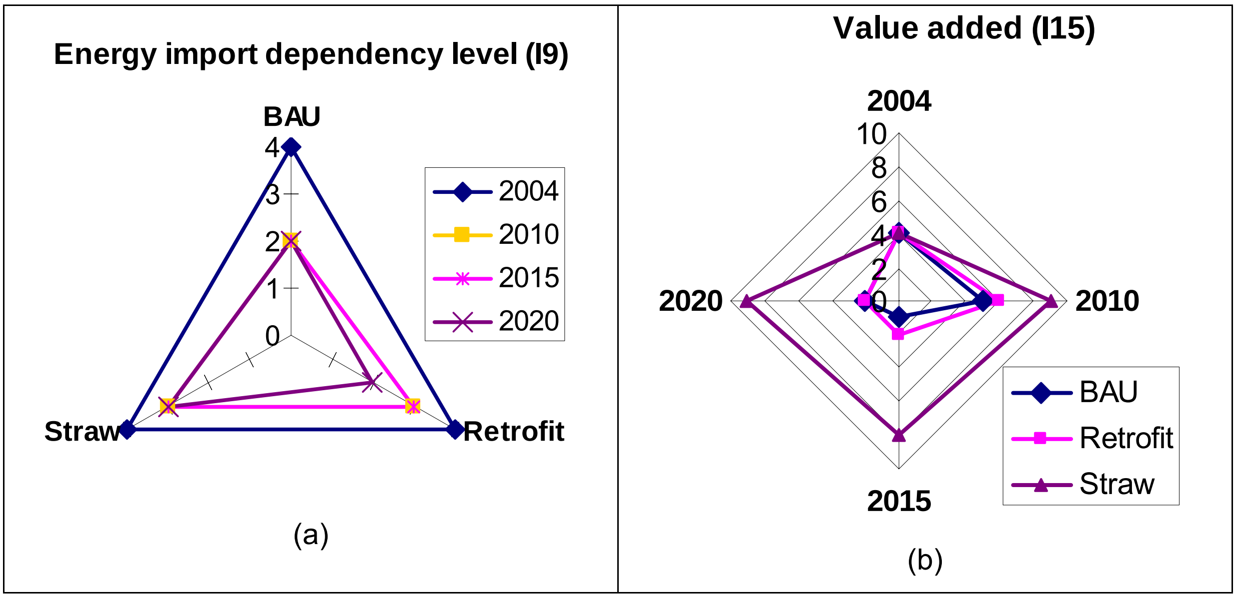


Figure 118: Energy import and value added indicators with their scores

Besides the macroeconomic development, a region must also ensure the enhancement of its economic situation at micro level. Thus, gross margin of individuals and firms should be increased considering market mechanism. The value added (VA), referring to the contribution of the factors of production to raising the value of a product, contributes to both micro and macroeconomic development. Figure 118b shows its development resulting from the energy sector in Borsod. Value added has the lowest degree in BAU case in the whole period: in year 2004 it has the value 4 among scores, but because of the decreasing fuel extraction activities it will worsen in the future. Contrarily, establishing biomass activities always contribute to the increase of regional value added, considering that costs of intermediate goods will be less, since less import of fuels and energy is required. Besides, the costs of factors of production will be higher and remain in the area. Straw scenario represents numerous local working places in the fields of agriculture, logistic, administration and others (since a huge amount of straw must be collected and transported by local workers). Therefore VA reaches score 9 in 2010. In 2015 it sinks a bit, because of the decreased energy production. Scores of value added increases up to 6 in Retrofit scenario, which seems to be a minor change when comparing to BAU. But when deducing interferences from such results, it must be taken into consideration, that value added includes the whole energy sector, therefore small changes are not always clearly observable.

In the year 2010 the Retrofit scenario has the highest costs, represented by the technological costs of the retrofit process, besides by the continuous establishment, cultivation, harvest and transportation of poplar. In 2020 both BAU and Retrofit will worse their scores, but Straw will even increase, being stabilized in the market. Total costs are included in the indicator Unit gross margin (the difference between revenue and total costs), shown in Figure 119. Since the indicator includes the whole regional average, small changes in the Retrofit case cannot be seen within this system. A summary of all economic indicators is given in Figure 120, and other figures are included in Annex XVII.

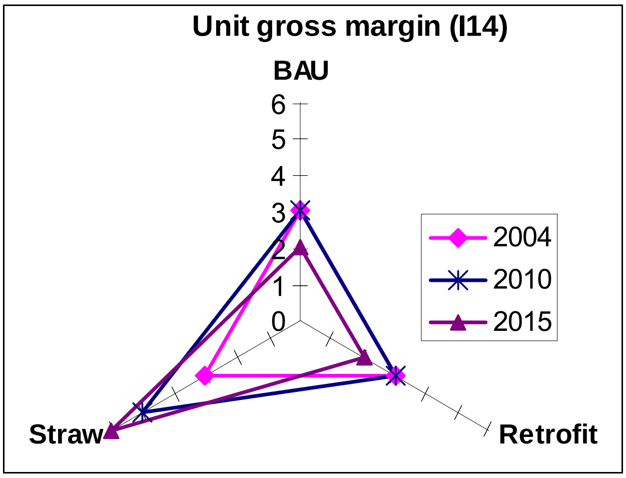


Figure 119: Representation of total costs and gross margin for a unit energy production

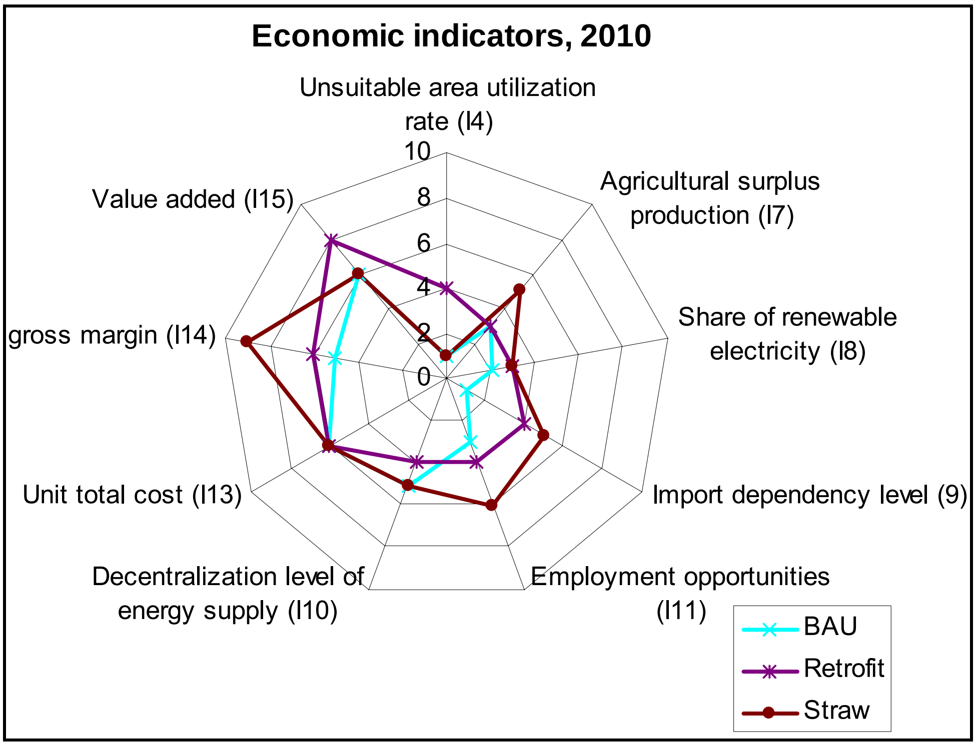


Figure 120: Summary representation of economic indicators

7.1.2. Social indicators

The social indicator Employment opportunities (shown in Figure 121a) denote the number of new working places generated in the energy sector of Borsod. In case of BAU scenario, it does not change in the future, since no new investments are considered, except the originally planned minor ones. Retrofit achieves a score of 4 in the year 2010, and then it decreases to 3 (in 2015) due to the closure of power plants (until 2013). Establishment of straw-fired plant represents a higher investment and more employment needed. Since it would operate in a longer run, for about 20-25 years, it results in scores 5 and 4 in the years 2010 and 2015 respectively.

As described in Chapters 4.4 and 6.4.1, there is a high correlation between unemployment and emigration, which explains the run of the second social indicator analyzed, the Emigration rate (see Figure 121b). Whilst BAU scenario remain on the same level (score 6 in 2010), Retrofit and Straw increase up to score 8. This is, because the more job opportunities, the more people staying in he area, decreasing in this way the emigration. The work required for the realization of Retrofit case appears mostly in the agriculture and forest sectors, while that of the Straw scenario in the agriculture. This signifies job places for "blue-collar" workers in rural areas facing significant economic problems. Because the majority of rural population is employed in the summer period, and the harvests of both biomass scenarios occur mostly in winter, biomass scenarios contribute to the alleviation of the temporal unemployment difficulties. On the contrary, Population shows a continuous downward tendency in the future, if no BtE alternatives are applied (BAU).

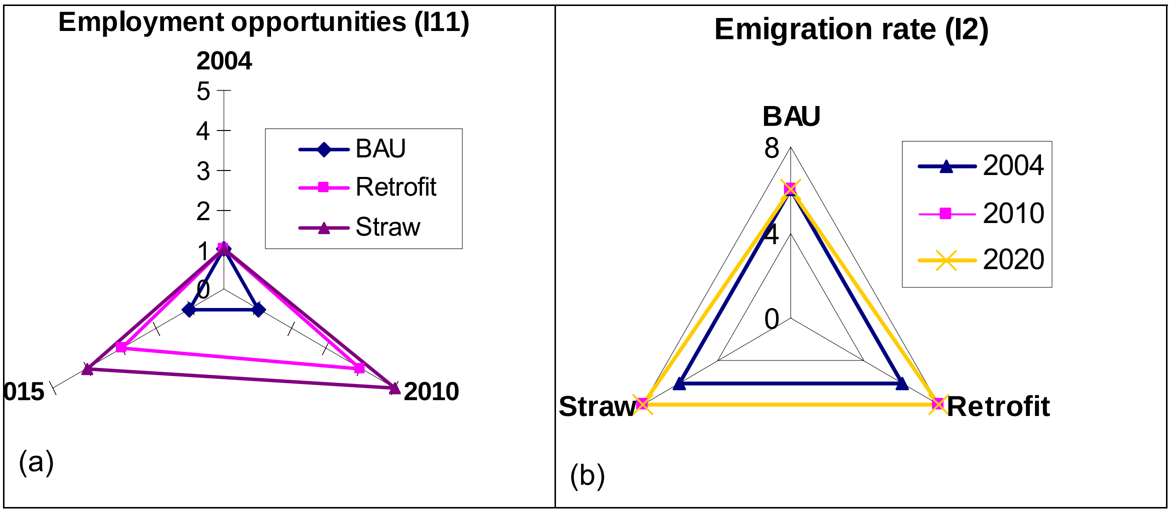


Figure 121: Scores of selected social indicators for various scenarios

Projecting the single indicators' scores on a summary figure allows analyzing them together, as given in Figure 122. According to the results, BAU has the lowest level in all indicator cases. Changes of decentralization level are minor, because whilst one new straw-fired plant will be built (straw), two other will run off. Straw scenario represents the most employment opportunities, but contributes to the decrease of emigration and increase of rural population at the same level than Retrofit. Further figures of social indicators assessment are presented in Annex XVII.

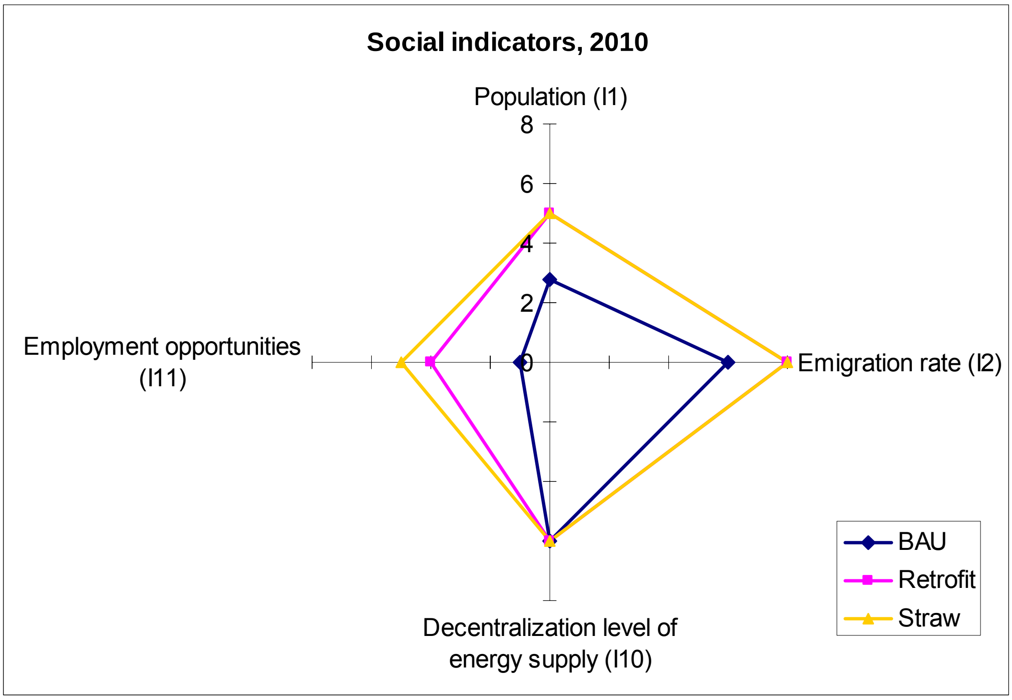


Figure 122: Social indicators in the year 2010

7.1.3. Environmental indicators

Among environmental indicators the air pollution-related Oxygen production is shown in Figure 123a. Due to the establishment of energetic plantations there is a significant increase of produced oxygen in the area, represented by Retrofit scenario. BAU and Straw only slightly increase oxgen production over time, resulting from the continuously increasing forest areas, according to the sustainable forest management.

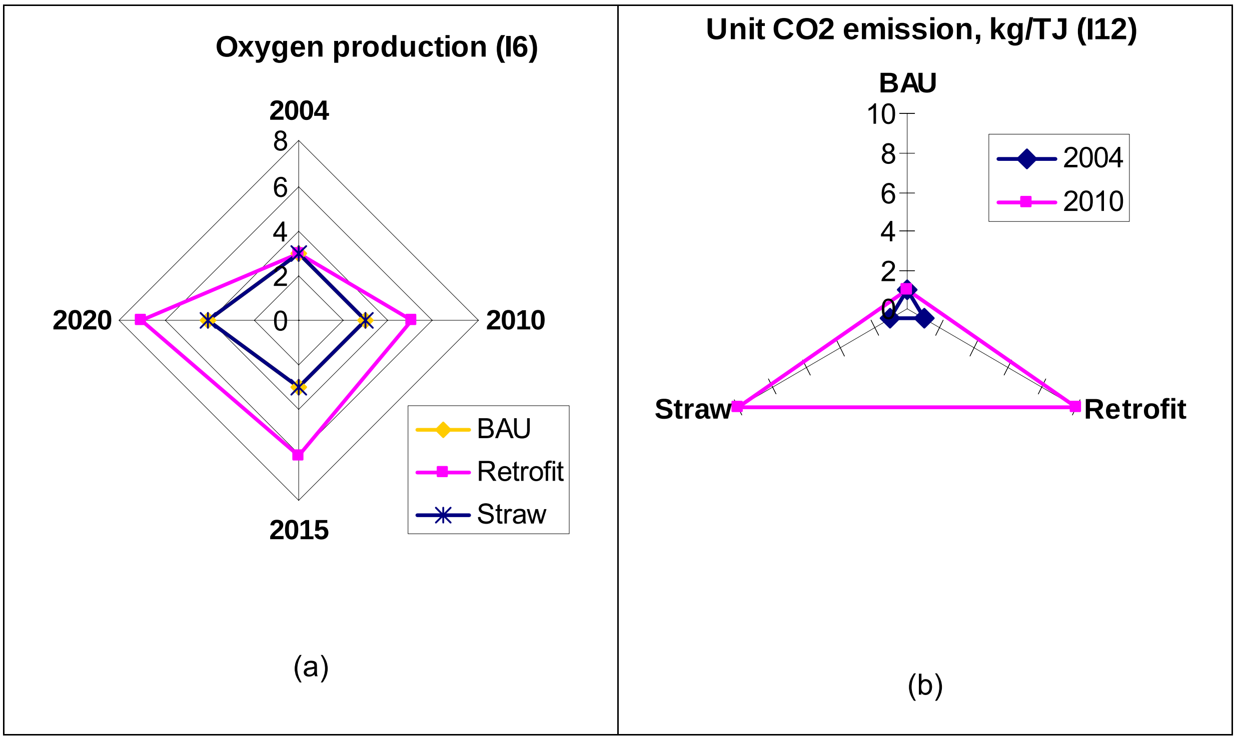


Figure 123: Score of selected environmental indicators

CO_2 emission is calculated as its replacement amount, comparing to the amount emitted by one TJ energy generation based on coal. In Retrofit case it is the CO_2 emission resulting from using firewood for energy generation, and in Straw casefrom using straw. Taking into consideration that biomass conversion is regarded to be CO2-neutral, there is a significant difference between BAU and renewable scenarios. The built model calculates not only emissions resulting from conversion processes, but also from the poplar establishment, cultivation, and harvest, transportation of all fuels, etc. Since those emissions are significantly lower than the ones resulting from fossil use, renewables reach the score 10 within the current system. The indicator Energy plantation index influence the sustainable land use within a region, contributing to environmental enhancement. The diversification of agricultural products might increase biodiversity, avoiding the too large plantations and monoculture. The two latter indicators are included in Annex XVII, whilst the summary of all environmental indicators is shown in Figure 124.

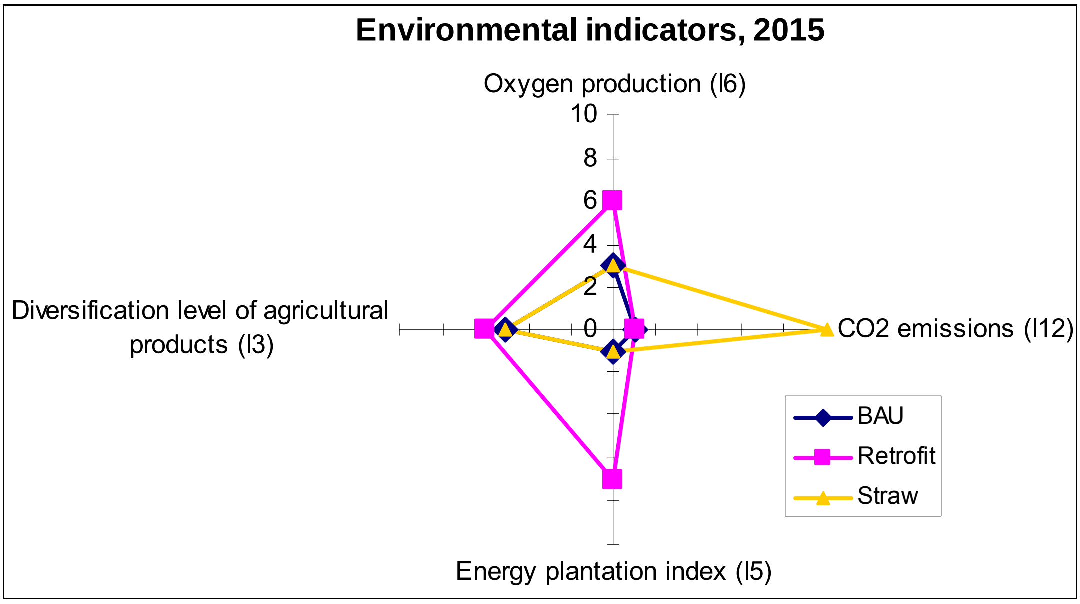


Figure 124: Environmental indicators scores for BtE scenarios

In general it must be noticed, that an appropriate set of the utility functions and so the scores of indicators can be achieved by an iterative process, where decision makers, stakeholders and the system developer should participate. It also must be added, that presented figures represent results of a semi-hypothetical data-set and the opinion of a certain stakeholder group. All indicators contribute to the overall sustainable development of Borsod according to their defined preferences, which are introduced as follows.

7.2. Achievements of the overall sustainable development

After applying various scenarios within the built model, interested variables (indicators) can be analyzed, as well as their quantitative contribution towards sustainable regional development. The latter is achieved via implementing the indicators into the objective system and calculating the main goal with the given weights. The results of that are presented in Figure 125, showing the sustainability level in the selected years. The theoretical maximum value of sustainability level can be 10, if all indicators have the scores 10. This is clearly not a realistic level; in 2004 all scenarios had the value of 3.85. In 2010 BAU has decreased to 3.44 and in 2020 to 2.49. That shows how the level of sustainability worse if there is no significant change in the energy sector. All pillars of sustainabilit decline in BAU case, since the energy sector has several regional effects and impacts, and components interrelate with each other dynamically. Retrofit shows an increased sustainability level in 2010, it reaches 5.03. No further development can be seen after this period, because of the actual capacity plans. According to them, the energy demand will be covered by sources outside of the region, which signifies higher dependency and costs, less value added and worse environmental quality, therefore the overall sustainability level fall. Surely other solution will be found in Borsod to supply the energy demand, which must aim an overall sustainable development.

Establishing and operating straw-fired plant will contribute to the sustainability in both mid and longer term. However, this positive evaluation can be interpreted from the fact that value added is considered with a very high preference in relation to the other indicators. Therefore, even though there is a high investment cost and, - comparing to fossils - higher running costs, through creating significant value added and contributing to the security level, green electricity generation, etc., the final evaluation is positive within the given evaluation system.

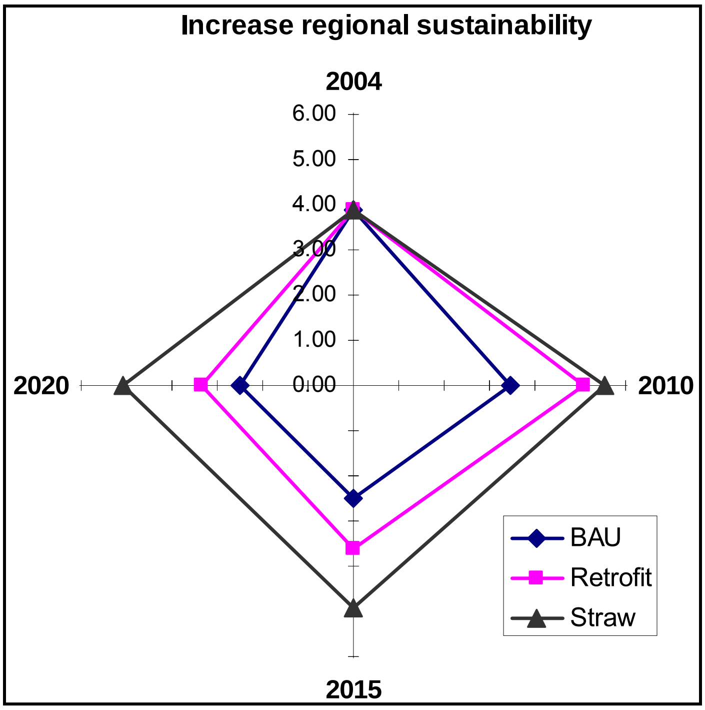


Figure 125: Sustainability level of defined scenarios in the future

Figure 126 and Figure 127 contain the scores for the sectors of sustainable development, such as economic, social and environmental development. According to that, Retrofit has higher environmental enhancement, whilst Straw is considered as contributing more to economic and social development. Further figures and results are presented in Annex XVII. It must be noted once again, that the circumstances in which such results occur must be understood and analized, before drawing final conclusions. For example, only the Straw alternative will run until the end of period, and represents a bigger capacity (~50 MW) than Retrofit (~30 MW). Besides, a huge amount of historical data has been collected and processed, but using other sources, forecasts and methods for their future determination will result in diverse quantitative outputs. Certainly, other participants will propose different preferences among objectives and indicators, and even new indicators could be proposed. All these aspects can be integrated into the tool-set in the future, being a white-box open system.

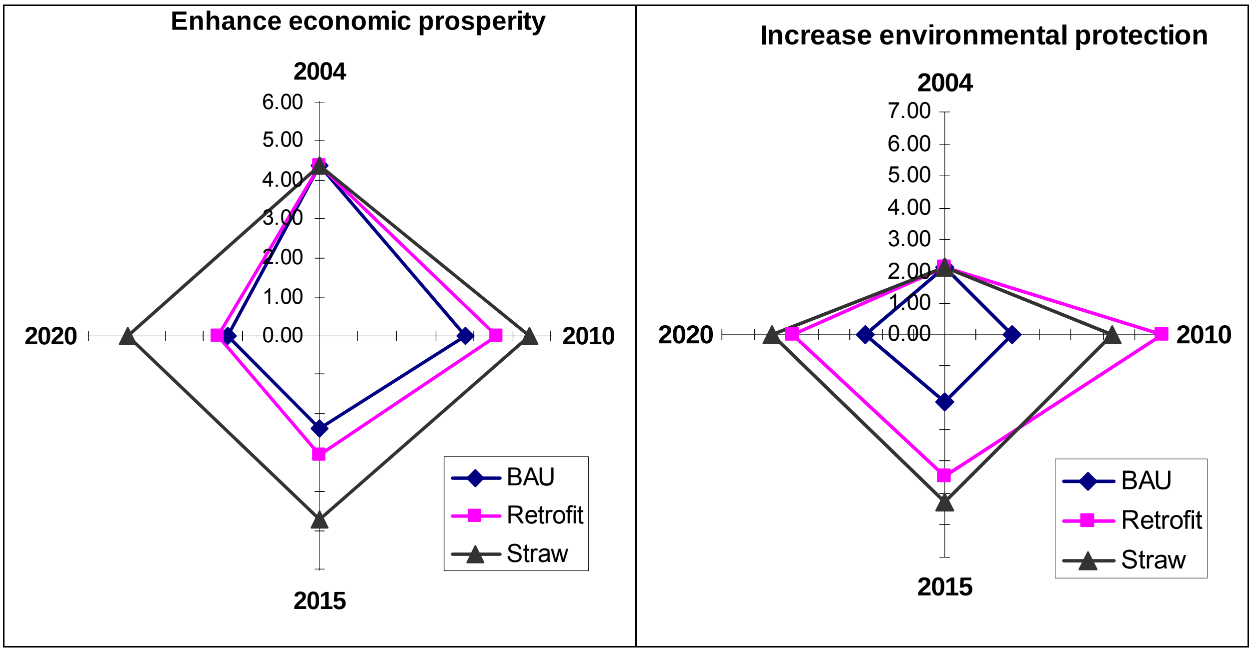


Figure 126: Scores of economic and environmental components of sustainability for biomass scenarios

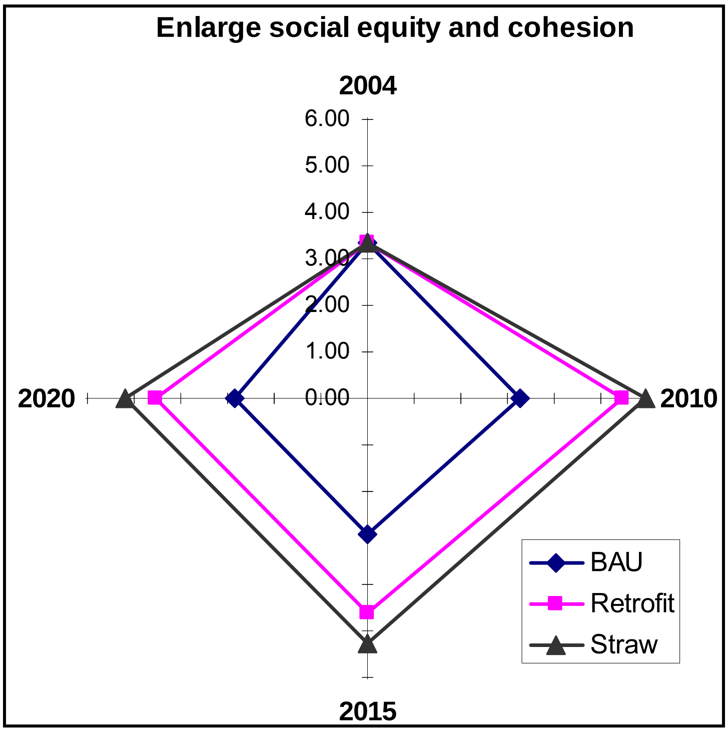


Figure 127: Scores for social development in Borsod

8. Conclusions

Goal of this work was to develop an integrated dynamic tool-set for analyzing and evaluating regional effects of different biomass to energy alternatives. Various tools and methods have been utilized and connected, where the advantages of each tool are meant to complement the weaknesses of the others, thus making a stronger analysis. In order to build, calibrate and validate the model, the region of BAZ in Hungary was selected. First a complex analysis of the region was carried out to define problems and objectives using various tools and methods. Empirical biomass alternatives were defined using derived indicators, which were simulated with the built system dynamics model. Conclusions drawn from each parts of the study are presented hereon.

8.1. Analysis of the case-study region BAZ in Hungary

An overall analysis of Borsod was carried out in order to perceive its historical and present situation. Information and data were collected from diverse sources, and processed using various methods. In several cases, data were found with diverse numerical values, depending on sources and methods, which were considered in this study. Through the collection and consequent managing and documenting data and their sources, a data base and metadata base was established, which can be used for other studies in this area or research field. Methodologies for data calculations in statistics and elsewhere were found that have been going through several modifications during previous years, which were clarified, synthesized and applied within this study.

The demographic, economic and environmental situation of Borsod was presented both in a descriptive and in a quantitative form. Results of this analysis should be taken as informative because of the limited data available; however, they give a realistic figure of the county, when comparing to literature. Furthermore, a system analysis was carried out, resulting in identified problems, SWOT assessment and objectives. To achieve those successfully, it can be concluded that active involvement of stakeholders at various level of participation and decision making is required, to include the objectives and preferences of all. Main result of this activity was the structuring of a network objective structure, based on the three pillars of sustainable development (that is, economic, social and environmental objectives), and focused on bottom-level regional perspective of energy generation. Nonetheless, it must be noted, that according to the opinion of all consulted stakeholders, most objectives are related to the economy, having significant preferences. Main specific economic objectives identified are the increase of value added and gross margin, alleviate dependency on imported fossil fuels, contribute to more renewable electricity. The social development should be achieved through enhancing rural conditions by generating new jobs and retaining the population. Among environmental objectives the most relevant ones are in correspondence with European and national goals, such as reducing CO_2 emission and contribute to sustainable land use and biodiversity enhancement.

The results of the system analysis were useful for defining three regional scenarios for future possible use of biomass. The developed scenarios can be considered realistic, since they include the identified objectives with stakeholders participation, and because they are based actual possible future investigations to be performed in Borsod. Besides the “Business as usual” (BAU) scenario, which contemplates future regional development without fostering of biomass use for energetic purposes, two main scenarios (“Retrofit” and “Straw”) are related to energetic use of the biomass produced in the agriculture and forest sectors. Retrofit corresponds to the retrofit of a coal-based boiler to biomass use, supplied by traditional forests and SRC plantations. Straw scenario denote to the establishment of a straw-fired plant in the region, using agricultural residues.

8.2. Establishment of the system dynamics model

After carrying out all preliminary regional assessments, a system dynamics model was built and calibrated for Borsod. The developed model has integrated all regional components considered relevant for a thorough analysis of biomass options. It also entails the scopes of social, economic, and environmental objectives. The model consists of seven sub-models, covering the population, economy, agriculture, forests, land cover and energy sectors. The construction of the developed model can be therefore considered as assembling all relevant sectors of study in the energy field when focusing on a regional basis.

An important feature of the model is that it includes interactions and feedbacks, which take place in a real world, such as in a region. Therefore dynamic and feedback components can be represented in a realistic way.

Moreover, all sub-models' results can be analyzed independently, although the sub-models are actually connected to each other. Model variables are clearly distinguished according to their functions and type, which facilitate the orientation among them. Equations are implemented in a way that only minor changes are needed when setting alternatives. All these features make the system "understandable", meaning that the division into sub-models, the use of subscripts for connecting the different calculating planes, and the simple programming of the model makes the system clear and open for integration with further-developed components. In fact, all variables and subscripts can be complemented in case of future use, which can be represented through transferring the model to other reference areas, or implementing other sectors, for example further renewable energy sources. Besides, other defined scenarios can be applied, without actually requiring significant effort. Using WHAT-IF technique scenarios can be followed and partial change of the system can be observed and analyzed.

Finally, about the development and calibration of the model functions, it is important to mention that all the used data are based on a huge collection and processing activities performed at the early stages of this investigation. Therefore, such data can be taken as reliable information. Calibration itself was made using data series and integrated techniques, by fitting calculated variables of the model to real (measured) historical data series. Such historical matching allows to change input variables within a possible range (sensitivity) in order to generate modeled output best fitting to measured ones. As a result, the model provides with a realistic overview on the assessed sectors and variables, information that depending on the end user's preferences can be given graphically and/or as a written report.

8.3. Application of the developed dynamic system in the case study region of BAZ

Biomass scenarios have positive effect on the social situation in BAZ, because the implementation of the foreseen new alternatives requires more work forces in the region, thus representing employment possibilities for local people. Additionally, most of the work demand occurs in the winter period, where the unemployment among "blue-collar workers" in rural areas is the highest. Since employment and emigration has a high correlation, according to historical data analysis, this also retains local population.

In this sense, the Straw scenario contributes the most to employment generation, considering that the Retrofit scenario supposes the closing of power plants. Economic development can also be realized in case of both renewable alternatives, which is the highest in Retrofit case in a mid term (in year 2010). Among economic variables, costs are higher when biomass scenarios are realized, but the value added associated to these scenarios increases significantly in both cases. Retrofit contributes the most to the use of unsuitable areas, affecting also the surplus production (that is, poplar plantations instead of traditional wheat and maize). On the other hand, the Straw scenario increases the most the share of renewable electricity production and therefore reduces Borsod's dependency on import fuels.

The assessment of the diversification level of agricultural products and energy plantation index, makes clear that the Retrofit scenario increases the environmental state of the county more than Straw and significantly more that BAU scenario. Taking a look to the overall results it was determined that both Straw and Retrofit scenarios have positive effects in comparison to BAU in the mid- and long-term.

From all the above results and discussions, it can be concluded that the inclusion of a renewable energy source such as the biomass from forest and agricultural activities can positively contribute to regional development, especially in the case of the Borsod region in Hungary. Additionally, because of its open construction, the model can be followed step by step, and therefore it can be implemented in other regions, after an appropriate adaptation and calibration. Furthermore, it is a flexible tool, and therefore other stakeholders involved within, which would provide a new dimension of opinions in the analysis and therefore adjusting the preferences of the indicators and the objectives to be achieved. Moreover, the open construction of the toolset makes it possible to implement further scenarios into the evaluation. Not only that, it is possible to utilize the system in other areas, such as different energy systems or renewable energy sources. All of the above has proven that the developed system can be considered as an innovative and flexible decision-support tool for identifying future energy solutions at regional level.

9. Summary and outlook

The introduction of this work (Chapter 1) establishes the importance and role of access to energy in modern times, as it influences the economic, environmental and social systems in a local, regional and/or global level. Historical experiences and future estimations and forecasts also point out the problems and negative effects of the sector, calling the attention to the need of new and renewable supply alternatives.

Hungary, a member state of the EU must fulfill national, European and international undertakings regarding energy saving, efficiency and increased use of renewable resources, among them biomass. Several problems and factors hindering the fulfillment of them have been identified and listed in Chapter 1. As example, the shortcoming of appropriate tools and methods can be named for a complex assessment about the availability of biomass, the viability of their use and the evaluation of their possible regional effects.

Considering all of this, the objective of this work was set, as to develop and implement a flexible method to evaluate the potential and use of biomass at local level, representing with a dynamic and feedback system and other assessment tools.

An overview of the most relevant aspects related to the work is presented in Chapter 2. This section introduces the concept and background of sustainability and its objectives and achievements. The energy sector is then thoroughly analyzed in terms of basic terms, units of measurement and commodity flows specifically considering the aspects related to biomass, core of the developed work. Afterwards the European and Hungarian historical, present and expected future figures are described and analyzed. The theory and application of decision making and decision support systems are also introduced, as well as the system dynamics modeling, an approach applied within this study.

In the scope of methods applied (Chapter 3), the strategy followed for the development of the work is introduced. The selected strategy involves first the analysis of the region of the Borsod-Abaúj-Zemplén (BAZ), which is presented in Chapter 4. This work step starts with setting the spatial, temporal and system boundaries around the study as well as with the identification, collection and process of information required. Subsequently the complex analysis of Borsod County has been performed. Through this analysis qualitative and quantitative information and data from the year 1990 have been gathered and processed in the sectors of demography and social situation, economy, industry, agriculture, forests and their management, environmental compartments and the energy situation. To carry out the latter one, energy production has been analyzed based on both fossil and renewable fuels. Consumption figures have been developed in details for each sector of use.

Chapter 5 gives the results from the region, when analyzed as a system. Within this system analysis, the following achievements can be found: identification of important stakeholders, problem and SWOT analyses and the establishment of a network of objectives for energy development. Objectives have been weighted according to their relative importance using established methods (AHP). Indicators have been derived from the bottom level of the objective system, and also set with their utility functions, calibrated and weighted. The last section presented in this Chapter was the identification and quantification of realistic scenarios based on the gathered information.

System dynamics modeling of Borsod has been carried out and described in Chapter 6. The process started with a general introduction to the software applied, and the steps of building the model and set its components and units. The model has been divided into so called sub-models for better handling it: population, land-cover, agriculture, forest, energy balance. There are 215 variables, with 32 subscripts implemented, which can be followed in the examined period, between 1990 and 2020. Historical matching of the built model was performed, as well as a sensitivity analysis, before simulating the defined scenarios. Results of simulations are displayed in graphs and tables, for analyzing and comparing them.

Selected quantitative indicators have then been implemented into the objective system, the results of which can be seen in Chapter 7. The achievements of sustainable development can be therefore compared when applying different scenarios. Analyzing the obtained results it has been proven that the Retrofit scenario, though slightly over the Straw scenario, increases the environmental state of the county the most, especially when compared to the results of the BAU scenario. Such results imply that scenarios related to energetic use of the biomass produced in the agriculture and forest sectors have considerable positive effects in the region in the mid- and long-terms.

The toolkit has been designed and constructed in an open and flexible manner, and therefore it is possible to implement other stakeholders, which would provide a new dimension of opinions and therefore adjusting the preferences and the goals to be achieved in the analysis. Moreover, these construction characteristics make it possible in the future to implement further scenarios into the evaluation. Furthermore, there is the possibility of utilizing the system in other areas, such as different energy systems or renewable energy sources. The developed tool-set can be therefore considered as a novel, sound approach for evaluating energy strategies at a regional level.

There are several parts of the tool-set open for developed in the future, when applying it for new scenarios, other regions or fields of research. Regional analysis can be followed as presented, taking into consideration that when other biomass sources are applied, their sectors must also be represented (for example biogas from sewage sludge or bio-waste, etc.). Objectives and indicators assessment will also be complemented according to the subjects proven as having highest importance. More intensive involvement of stakeholders can contribute to stronger participation of local players and decision makers.

The system dynamics model can include several new variables, subscripts and even new sub-models if needed, which must be integrated and connected to the whole established model.

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11. Index

11.1. Abbreviations

AGRORES: A Global Overview of Renewable Energy Sources

AHP: Analytic Hierarchy Process

ANP: Analytic Network Process

BAZ: Borsod-Abaúj-Zemplén (Borsod) county

BSI: German Association of Solar Industrialists

BU: Bottom-up

BUWAL: Bundesamt für Umwelt, Wald und Landschaft, Austria

CAP: Common Agricultural Policy

CHP: Combined Heat and Power

CI: Carbon intensity

DM: Decision Making

DPSIR: Driving-Force, Pressure- State- Impact- Response

DSR: Driving- Force- State- Response

DSS: Decision Support Systems

EC: European Commission

EEA: (1) European Environment Agency
(2) European Economic Area

EFTA: European Free Trade Association

EK: Energia Központ (Energy Centre, Hungary)

ÉMÁSZ: Èszak-Magyarországi Àramszolgáltató Rt (North-Hungarian Power Distributor Ltd.)

ÈMI-KTVF: Észak-magyarországi Környezetvédelmi, Természetvédelmi és Vízügyi Felügyelőség (North Hungarian Environmental Protection, Nature Preservation and Water Inspectorate)

ETBE: Ethyl tertiary butyl ether

EI: Energy intensity

EU: European Union

EU15: The EU prior to its expansion in May 2004

EU25: The EU after its expansion in May 2004

Eurostat: Statistical Office of the European Communities

EWEA: European Wind Energy Association

FAO: Food and Agriculture Organization of the United Nations

FVM: Földművelésügyi és Vidékfejlesztési Minisztérium (Ministry of Agricuture and Rural Development)

GHG: Greenhouse gas

GIC: Gross Inland Consumption

GKM:	Gazdasági és Közlekedési Minisztérium (Ministry of Economy and Traffic, Hungary)
GDP:	Gross Domestic Product
IAP2:	International Association for Public Participation
ICLCEPT:	Imperial College London Centre for Energy Policy and Technology & E4tech Consulting
IEA:	International Energy Agency
IIASA:	International Institute for applied System Analysis
IPPC:	Intergovernmental Panel on Climate Change
KSH:	Központi Statisztikai Hivatal (Hungarian Central Statistical Office – HCSO)
KVM:	Környezetvédelmi és Vidékfejlesztési Minisztérium (Ministry of Environmental Protection and Rural Development)
LAU:	Local Administrative Units
LCA:	Life Cycle Analysis
LFA:	Logical Framework Approach
MAVIR:	Magyar Villamosenergia-ipari Átviteli Rendszerirányító Zártkörüen Müködö Részvénytársaság (Hungarian Transmission System Operator Company Ltd)
MBH:	Magyar Bányászati Hivatal (Mining Bureau of Hungary)
ME:	University of Miskolc, Hungary
MET:	Ministry of Economy and Transport, Hungary
MKK:	Magyar Köztársaság Kormánya (Government of the Hungarian Republic)
Mtoe:	Mega tonne oil equivalent
MTSZ:	Magyar Természetbarát Szövetség (Hungarian Nature Protection Association)
MW:	Megawatt
MWe:	Megawatt electrical
NACPH:	National Association for Consumer Protection in Hungary
NORDA:	Regional Development Agency of North-Hungary
NUTS:	Nomenclature of Territorial Units for Statistics
OECD:	Organisation for Economic Co-operation and Development
OMSZ:	Országos Meteorológiai Szolgálat (National Meteorological Office, Hungary)
PSR:	Pressure- State- Response
PV:	Photovoltaic
RA:	Reference area
RES:	Renewable energy sources
RICH:	Rank Inclusion in Criteria Hierarchies
RME:	Rapeseed Methyl Ester
R&D:	Research and Development
SA:	Sensitivity analysis
SAPS:	Single Area Payment Scheme
SMART:	Simple Multi Attribute Rating Technique

SME:	Small and medium enterprises
SRC	Short Rotation Coppice
SD:	Sustainable development
SWOT:	Strength, Weakness, Opportunities, Threats method
TD:	Top-down
Toe:	Tonne oil equivalent
TWh:	Terawatt-hour
UBA:	Umwetbundesamt, Austria
UN:	United Nations
UNEP:	United Nations Environment Program
USDE:	US Department of Energy
VA:	Value added
W:	Watts
WED:	Western Economic Diversification Canada
WWEA:	World Wind Energy Association

11.2. List of Figures

11.3. List of Tables

ANNEX

ANNEX I. Main applied units

Energy					
	To :	TJ	Gcal	Mtoe	GWh
From:					
			multiply by		
TJ		1	238.8	2.388×10^{-5}	0.2778
Gcal		4.1868×10^{-3}	1	1×10^{-7}	1.163×10^{-3}
Mtoe		4.1868×10^{4}	1×10^{7}	1	11630
GWh		3.6	860	8.6×10^{-5}	1

Denomination	Unit
General	
Without dimension	Dimensionless (Dmnl)
Time	Year (a)
	Hour (h)
Quantity	Tonne (t)
	Kilogram (kg)
Fiscal values	Euro (EUR)
Piece	(Piece)
Per capita amount	(/capita)
	(Person)
Share	Percentage (%)
Agriculture and forest sector	
Production (forest)	Cubic meter (m3)
Area	Hectare (ha)
Animal unit	Cattle unit (CU)
Energy sector	
Capacity/production/consumption	Tera joule (TJ)
	Megawatt (MW)
	Megawatt-hour (MWh)
Transport unit	Tonne kilometre (tkm)

ANNEX II. Selected biomass based heat and power plants in Europe

Plant type	Solid bed biomass gasification	Fast Internally Cycling Fluidised Bed biomass gasification	Biomass heating station with steam engine	Biomass ORC-station 1	Biomass ORC-station 2	CHP plant	Straw power plant	Power plant 1	Power plant 2	Power plant 3	Power plant 4	Heat plant 1	Heat plant 2
Location	Schwanberg, Austria	Güssing, Austria	Lengwil, Switzerland	Biere, Switzerland	Kaszó, Hungary	Wien-Simmering, Austria	Szerencs, Hungary	Kazincbarcika, Hungary	Salgótarján, Hungary	Pécs, Hungary	Ajka, Hungary	Szent-endre, Hungary	Balassa-gyarmat, Hungary
Technology	solid bed gasification	Fast Internally Cycling Fluidised Bed gasification				CFB boiler, pass-out condensation turbine, SNCR, SCR	conventional condensation water-steam cycle, steam turbine, straw fired boilers						
Net Electric capacity, MWe	0.3	1.74	0.4	0.335	1.1	12,9 in winter, 21,3 in summer	49.91	30	6	49.9	25	1.4	2
Net Heat capacity, MWth	0.4	4.5	6.4	1.44	5.6	37 in winter	0	0	16			9	
Operation hours, h/a	7,000	7,000	7,000	7,000	7,500	8,000	8,000						
Feedstock type	woodchips	woodchips	bark residues, timber residues	woodchips	woodchips	woody biomass	Hesston straw bales	woodchips, sunflower shell, sawdust	forest wood (from the Ipoly Forest ZRT.) + energy wood	biomass	biomass	biomass	biomass
Feedstock demand, t/a	1,932	12,600	13,230	4,704	3,500	10,778	190,000	250,000	19,0000-35,0000	380,000	193,000	20,000	12,000
Produced net electric energy, MWh/a	2,100	12,180	2,800	2,345	8,200	167,000	394,500	220,000		360,000	192,000	8,000	16,000
Produced net heat, MWh/a	2,800	31,570	44,800	10,080	42,000	for 12000 households			44 500 for district heating purpose			61,111	38,889
Total efficiency, %		76.2	79	77.7		80% winter, 36% summer	32.23	28					
Electric efficiency, %	0.25	21.2	4.6	14.7	14		32.23	28					
Thermal efficiency, %	0.42	55	74.4	63	72		0	0					
Source	[Kolleger, 2007]	[Kolleger, 2007]	[Kolleger, 2007]	[Kolleger, 2007]	[Kolleger, 2007]	[Madlener and Bachhiesl, 2005]	[Zöldtech, 2006], [FigyelőNet, 2006]	[AES, 2004]	[Menedzsment Fóru, 2006], [Nógrád Hírlap, 2006]	[Bai, 2006d]	[Bai, 2006d]	[Bai, 2006d]	[Bai, 2006d]

ANNEX III. Energy balances of Hungary in years 1990, 1995, 2000 and 2004 (TJ)

Energy balance of Hungary 1990 **Unit.: TJ**

Name	Solid	Petroleum +gazolin	Oil products	Natural gas	Nuclear energy	Water-energy	Electric energy	Heat energy	Firewood*	Estimated Renewable	Communal waste	TOTAL
Production	188,181	78,495	10,227	159,583	149,668	641			11,679	18,488	1,000	617,962
Other production	0	16,136	0	0					0			16,136
Import	65,768	263,138	67,090	217,300			47,876		0			661,172
Export	23		68,470	836			7,747		1,435			78,511
Change in stock	14,222	-22,755	-837	-2,874					-843			-13,087
Statistical difference	0	0	0	0					0			0
Consumption	268,148	335,014	8,010	373,173	149,668	641	40,129	0	9,401	18,488	1,000	1,203,672
Conversion	-138,182	-334,888	297,129	-104,351	-149,668	-641	102,370	95,730	-790	0	-1,000	-234,291
Petroleum Refinement		-334,888	333,091									-1,797
Ahydrálás	-233								-428			-661
Coking	-11,966								0			-11,966
City-gas production	0								0			0
Briquett	5,152		-6,351						0			-1,199
Electricity prod.for public purpose	-93,810		-9,517	-33,882	-149,668	-641	96,066		0			-191,452
Electricity and heat prod.for public purpose	-22,155		-5,560	-28,021			2,801	45,036	0		-1,000	-8,900
Heat prod.for public purpose	-8,430		-3,610	-12,034				18,764	0			-5,310
Electricity prod.for own use	-371		-73	-527			123		0			-848
Electricity and heat prod.for own use	-1,095		-3,233	-3,944			3,380	6,617	0			1,725
Heat prod.for .for own use	-5,274		-7,619	-25,943				25,313	-362			-13,885
Energy sector (own consumption)	0	0	-15,232	-11,013	0	0	-14,236	0	0	0	0	-40,482
Coal mining	0		-2	0					0			-2
Ahydrálás	0		0	0					0			0
Coking	0		0	0					0			0
City-gas production	0		0	0					0			0
Briquett	0		-153	-438					0			-591
Petroleum Refinement	0		-15,078	-10,575					0			-25,653
Electricity and heat prod	0		0	0			-14,236		0			-14,236
Loss	-257	-126	-213	-10,404			-14,530		-3			-25,533
Final end use **	**129,709**	**0**	**289,693**	**247,405**	**0**	**0**	**113,733**	**95,730**	**8,608**	**18,488**	**0**	903,367
Non-energetic use	0		38,845	23,113								61,958
from what_ chemical raw material			25,223	23,020								48,243
Industry *	34,769	0	36,637	121,693	0	0	49,504	27,330	149	0	0	270,081
Iron and steel metallurgy	29,710		5,323	25,737			6,285	2,428	11			69,494
Chemistry*	2		6,079	20,883			11,606	10,048	1			48,619
Non-metal metallurgy	0		1,557	585			5,823	942	0			8,907
Production of non-metal minerals	3,272		6,037	29,448			4,122	711	10			43,600
Transporters and machines	0		1,178	3,371			1,325	763	0			6,637
Machine ind.	602		2,751	9,986			5,292	1,941	5			20,577
Mining	356		1,226	3,246			1,680	0	12			6,520
Food ind.	691		7,820	18,769			5,886	3,240	91			36,498
Paper and press	0		257	736			2,023	2,617	0			5,633
Wood ind.	0		445	1,274			752	0	0			2,471
Construction	84		1,873	1,873			724	271	17			4,841
Textil and leather ind.	49		1,890	5,355			2,995	3,474	2			13,765
Other industry	3		201	429			990	895	0			2,519
Traffic	60	0	120,666	5	0	0	3,965	77	0	0	0	124,773
air	0		6,712	0					0			6,712
road	0		106,562	5								106,567
railway	60		6,994				3,965	77	0			11,096
water			398	0			0		0			398
Households	83,847		48,694	66,120			33,080	34,758	7,371	18,488		292,358
Trade and services	9,648		18,235	28,686			20,236	30,431	568			107,804
Agriculture	1,385		26,616	7,788			6,948	3,134	520			46,391
Other												0
Hh+trade+agr+other	94,880	0	93,545	102,594	0	0	60,264	68,323	8,459	18,488	0	446,553

*Comment: * without chemistry raw materials*

*** including the non-energetic use*

Energy balance of Hungary 1995 **Unit.: TJ**

Name	Solid	Petroleum +gazolin	Oil products	Natural gas	Nuclear energy	Water-energy	Electric energy	Heat energy	Firewood*	Estimated Renewable	Communal waste	TOTAL
Production	130,149	68,388	11,327	158,583	152,883	590			15,875	18,870	2,200	558,865
Other		16,132										16,132
Import	67,048	240,629	69,577	231,608			11,556					620,418
Export	11,209		87,582				2,898					101,689
Change in stock	2,173	-1,148	-1,820	-6,063								-6,858
Statistical difference												0
Consumption	188,161	324,001	-8,498	384,128	152,883	590	8,658	0	15,875	18,870	2,200	1,086,868
Conversion	-125,034	-323,896	244,592	-87,729	-152,883	-590	122,461	73,740	-223	0	-2,200	-251,762
Petroleum Refinement		-323,896	314,811									-9,085
Ahydrálás												0
Coking	-5,223											-5,223
City-gas production												0
Briquett	961		-1,336									-375
Electricity prod.for public purpose	-91,876		-48,868	-42,444	-152,883	-590	116,982					-219,679
Electricity and heat prod.for public purpose	-19,481		-9,881	-17,621			2,535	34,692			-2,200	-11,956
Heat prod.for public purpose	-2,808		-2,034	-4,912				9,755				1
Electricity prod.for own use	-658		-72	-326			148					-908
Electricity and heat prod.for own use	-3,904		-2,218	-3,119			2,796	5,326				-1,119
Heat prod.for .for own use	-2,045		-5,810	-19,307				23,967	-223			-3,418
Energy sector (own consumption)	0	0	-12,627	-10,926	0	0	-14,147	0	0	0	0	-37,700
Coal mining												0
Ahydrálás												0
Coking												0
City-gas production												0
Briquett												0
Petroleum Refinement			-12,627	-10,926								-23,553
Electricity and heat prod							-14,147					-14,147
Loss	-20	-105	-53	-14,815			-17,096					-32,089
Final end use **	**63,107**	**0**	**223,414**	**270,658**	**0**	**0**	**99,876**	**73,740**	**15,652**	**18,870**	**0**	765,317
Non-energetic use	2,536		49,938	15,950								68,424
from what_ chemical raw material			28,424	14,555								42,979
Industry *	28,865	0	21,647	75,188	0	0	30,168	18,762	110	0	0	174,740
Iron and steel metallurgy	25,508		1,442	13,108			2,606	1,501	5			44,170
Chemistry*			5,353	17,256			7,569	7,485				37,663
Non-metal metallurgy			206	2,016			2,893	2,160				7,275
Production of non-metal minerals	2,407		5,825	14,839			2,030	383	4			25,488
Transporters and machines	0		325	1,329			1,138	289				3,081
Machine ind.	296		1,350	4,991			3,317	780				10,734
Mining	1		67	306			990					1,364
Food ind.	452		5,062	14,807			4,460	2,276	50			27,107
Paper and press	21		275	1,499			1,462	2,379	4			5,640
Wood ind.	0		295	1,205			695					2,195
Construction	66		801	644			619	19	1			2,150
Textil and leather ind.	43		495	1,608			1,739	852				4,737
Other industry	71		151	1,580			650	638	46			3,136
Traffic	16	0	99,631	34	0	0	3,690	0	0	0	0	103,371
air			7,401									7,401
road			87,934	34								87,968
wrailway	16		4,257				3,690					7,963
water			39									39
Households	26,332		22,118	120,606			35,233	33,690	11,646	18,870		268,495
Trade and services	3,283		16,568	52,701			26,379	21,199	2,540			122,670
Agriculture	2,075		13,512	6,179			4,406	89	1,356			27,617
Other												0
Hh+trade+agr+other	31,690	0	52,198	179,486	0	0	66,018	54,978	15,542	18,870	0	418,782

*Comment: * without chemistry raw materials*
*** including the non-energetic use*

Energy balance of Hungary 2000 **Unit.: TJ**

Name	**Solid**	**Petroleum**	**Oil**	**Natural**	**Nuclear**	**Water-**	**Electric**	**Heat**	**Firewood***	**Estimated**	**Communal**	**TOTAL**
Production	121,120	47,485	10,152	103,629	154,562	641			14,925	18,100	2,436	473,050
Other		12,177										12,177
Import	53,719	242,440	49,254	307,613			22,309					675,335
Export	5,481		74,645	2,704			9,925					92,755
Change in stock	-525	-7,608	-357	-4,229								-12,719
Statistical difference												0
Consumption	168,833	294,494	-15,596	404,309	154,562	641	12,384	0	14,925	18,100	2,436	1,055,088
Conversion	-130,178	-291,018	243,618	-102,646	-154,562	-641	126,688	68,274	0	0	-2,436	-242,901
Petroleum Refinement		-291,018	288,756									-2,262
Ahydrálás												0
Coking	-8,158											-8,158
City-gas production												0
Briquett	221		-284									-63
Electricity prod.for public purpose	-90,878		-38,547	-33,819	-154,562	-641	109,487					-208,960
Electricity and heat prod.for public purpose	-31,351		-4,894	-48,094			15,408	49,536			-2,436	-21,831
Heat prod.for public purpose	-12		-907	-14,679				14,927				-671
Electricity prod.for own use				-45			25					-20
Electricity and heat prod.for own use			-506	-2,790			1,768	1,099				-429
Heat prod.for .for own use				-3,219				2,712				-507
Energy sector (own consumption)	-11	-3,476	-19	-8,404	0	0	-18,475	-12,818	0	0	0	-43,203
Coal mining	-11											-11
Ahydrálás												0
Coking				-34								-34
City-gas production												0
Briquett												0
Petroleum Refinement		-3,476	-19	-8,370			-2,815	-6,176				-20,856
Electricity and heat prod							-15,660	-6,642				-22,302
Loss				-13,097			-17,424	-2,753				-33,274
Final end use **	**38,644**	**0**	**228,003**	**280,162**	**0**	**0**	**103,173**	**52,703**	**14,925**	**18,100**	**0**	735,710
Non-energetic use	1,969		48,423	13,668								64,060
from what_ chemical raw material			37,521	13,668								51,189
Industry *	22,979	0	20,999	56,851	0	0	26,992	13,557	0	0	0	141,378
Iron and steel metallurgy	18,253		44	5,253			2,085	912				26,547
Chemistry*	8		13,722	10,293			6,713	4,471				35,207
Non-metal metallurgy	0		38	3,543			3,198	2,201				8,980
Production of non-metal minerals	4,143		3,880	13,690			3,135	420				25,268
Transporters and machines	4		52	1,985			1,051	522				3,614
Machine ind.	327		308	5,262			2,440	289				8,626
Mining			188	49			356	5				598
Food ind.	152		2,235	10,852			3,930	1,555				18,724
Paper and press			329	2,569			1,837	1,742				6,477
Wood ind.	7		13	1,017			511	31				1,579
Construction	1		32	612			96	46				787
Textil and leather ind.	72		121	982			822	850				2,847
Other industry	12		37	744			818	513				2,124
Traffic	15	0	128,774	71	0	0	3,654	0	0	0	0	132,514
air			8,957									8,957
road			116,362	71								116,433
railway	15		3,423				3,654					7,092
water			32									32
Households	11,143		12,091	122,649			35,251	28,081	11,362	18,100		238,677
Trade and services	1,553		4,384	78,746			33,838	11,060	2,475			132,056
Agriculture	985		13,332	8,177			3,438	5	1,088			27,025
Other												0
Hh+trade+agr+other	13,681	0	29,807	209,572	0	0	72,527	39,146	14,925	18,100	0	397,758

*Comment: * without chemistry raw materials*
*** including the non-energetic use*

Energy balance of Hungary 2004 **Unit.: TJ**

Name	Solid	Petroleum +gazolin	Oil products	Natural gas	Nuclear energy	Water-energy	Electric energy	Heat energy	Firewood*	Estimated Renewable	Communal waste	TOTAL
Production	91360	45,012	10105	99090	129,874	738	22		25,088	20,350	1,374	423013
Other		9,071										9071
Import	51247	229,190	88931	388456			30963					788787
Export	3144	5,666	111682				4064					124556
Change in stock	6850	-2,213	-5269	-475								-1107
Statistical difference												0
Consumption	146313	275394	-17915	487071	129874	738	26921	0	25088	20350	1374	1095208
Conversion	-110873	-273161	259160	-149895	-129874	-738	121349	58900	0	-8651	-1374	-235157
Petroleum Refinement		-273,161	270227									-2934
Ahydrálás												0
Coking	-3391		-1694									-5085
City-gas production												0
Briquett	60		-82									-22
Electricity prod.for public purpose	-90304		-5954	-45588	-129874	-738	93474			-167	-1,374	-180525
Electricity and heat prod.for public purpose	-12836		-2365	-79836			26442	40841		-8,043		-35797
Heat prod.for public purpose	-4402		-403	-19781				15420		-165		-9331
Electricity prod.for own use												0
Electricity and heat prod.for own use			-569	-1986			1433	341		-276		-1057
Heat prod.for .for own use				-2704				2298				-406
Energy sector (own consumption)	-124	-2233	-2	-6441	0	0	-18361	-3110	0	0	0	-30271
Coal mining							-12					-12
Ahydrálás												0
Coking				-38								-38
City-gas production												0
Briquett												0
Petroleum Refinement		-2233		-6403			-3160					-11796
Electricity and heat prod	-124		-2				-15189	-3110				-18425
Loss				-14452			-15411	-3457				-33320
Final end use **	**35316**	**0**	**241243**	**316283**	**0**	**0**	**114498**	**52333**	**25088**	**11699**	**0**	796460
Non-energetic use	1402		47449	13454								62305
from what_ chemical raw material			41171	13454								54625
Industry *	23443	0	19452	54449	0	0	31428	14971	0	4457	0	148200
Iron and steel metallurgy	19139		41	5250			2133	875				27438
Chemistry*			7049	6367			6772	6,986		1,871		29045
Non-metal metallurgy	70		50	4023			3374	2,413				9930
Production of non-metal minerals	3707		7051	11473			3494	344		1,206		27275
Transporters and machines	59		834	2255			2689	738		18		6593
Machine ind.	98		80	6078			4096	198		93		10643
Mining	5		408	73			243			1		730
Food ind.	359		2212	12468			4902	1,110				21051
Paper and press	2		324	2777			2089	1,859		248		7299
Wood ind.			12	890			549	16		906		2373
Construction	1		1287	600			203	105				2196
Textil and leather ind.	3		19	994			763	274		2		2055
Other industry			85	1201			121	53		112		1572
Traffic	3	0	151152	82	0	0	3935	0	0	0	0	155172
air			8610									8610
road			139673	82								139755
wrailway	3		2814				3935					6752
water			55									55
Households	9796		8836	150926			39715	28,188	21,813	7,116		266390
Trade and services	417		2563	88430			35560	9,160	2,120			138250
Agriculture	255		11791	8942			3860	14	1,155	126		26143
Other												
Hh+trade+agr+other	10468	0	23190	248298	0	0	79135	37362	25088	7242		430783

*Comment: * without chemistry raw materials*

*** including the non-energetic use*

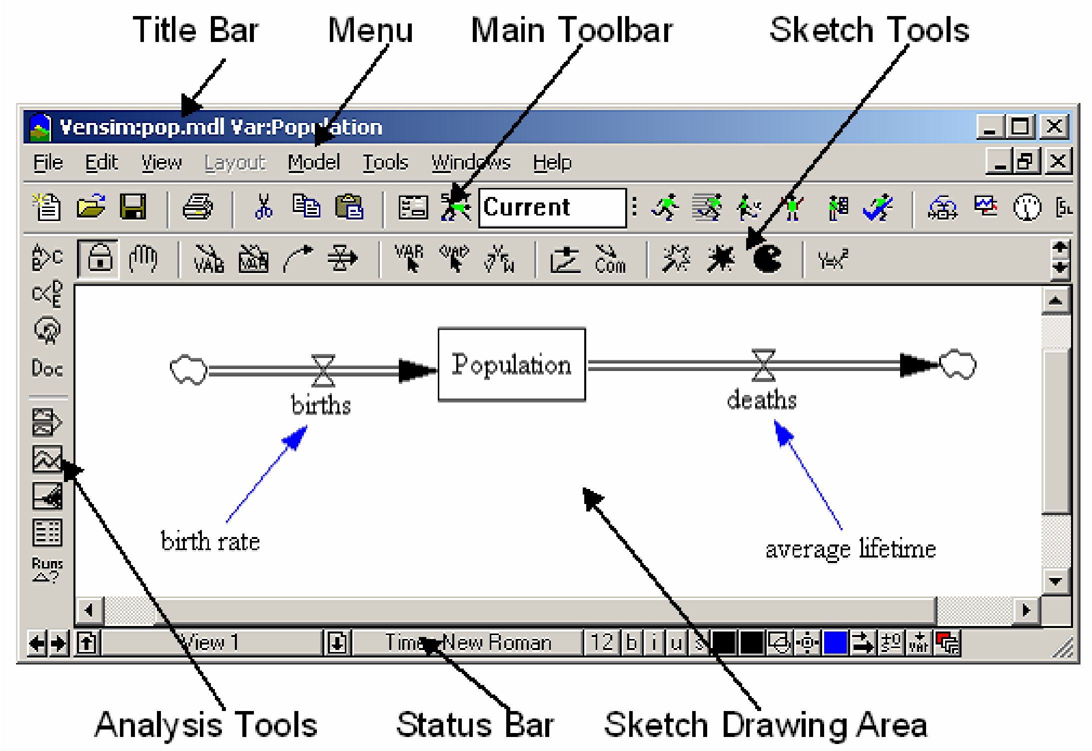
ANNEX IV. Technical description of the Software tool Vensim®

The Vensim User Interface

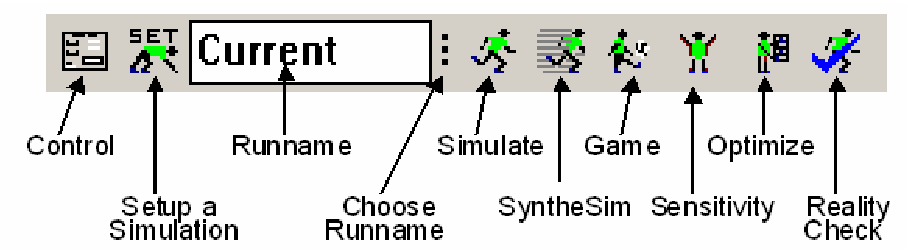
Main features, tools and elements of the Vensim® Software are summarized based on [Ventana Systems, Inc, 2006].

Main features

Vensim uses an interface that can be thought of as a workbench and a set of tools. The main Vensim window is the Workbench, which always includes the Title Bar, the Menu, the Toolbar, and the Analysis tools. When Vensim has a model open (as shown below), the Sketch tools and the Status Bar also appear.

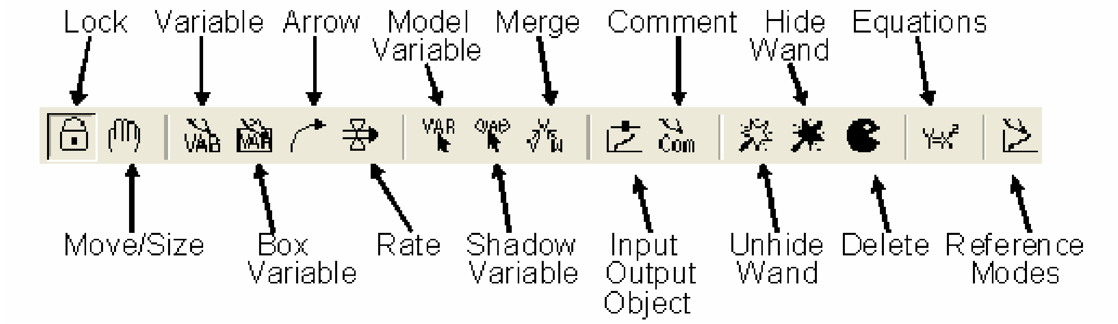


Functions used for simulating models are shown below.



Sketch tools

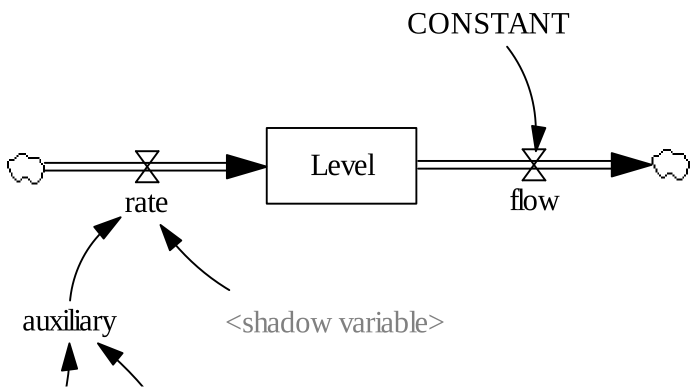
The most of the sketch tools needed for building models are grouped into a Sketch toolset as shown below.



- *Lock* — sketch is locked. Pointer can select sketch objects and the Workbench Variable but cannot move sketch objects.
- *Move/Size* — move, sizes and selects sketch objects: variables, arrows, etc.
- *Variable* — creates variables (Constants, Auxiliaries and Data).
- *Box Variable* — create variables with a box shape (used for Levels or Stocks).
- *Arrow* — creates straight or curved arrows.
- *Rate* — creates Rate (or flow) construct, consisting of perpendicular arrows, a valve and, if necessary, sources and sinks (clouds).
- *Model Variable* — adds an existing model variable and the causes of that variable to the sketch view.
- *Shadow Variable* — adds an existing model variable to the sketch view as a shadow variable (without adding its causes).
- *Merge* — merges two variables into a single variable, merges Levels onto existing clouds, merges Arrows onto a variable to split an Arrow, and performs other operations.
- *Input Output Object* — adds input Sliders and output graphs and tables to the sketch.
- *Sketch Comment* — adds comments and pictures to the sketch.
- *Unhide Wand* — unhides (makes visible) variables in a sketch view.
- *Hide Wand* — hides variables in a sketch view.
- *Delete* — deletes structure, variables in the model, and comments in a sketch.
- *Equations* — creates and edits model equations using the Equation Editor.
- *Reference Modes* — use to draw and edit reference models.

Graphic elements

With the tools introduced above the model building can be started graphically in the user interface. The model sketch graphic elements representing the structure of a system have different meanings and behavior. In the followings the most important elements are presented and described.



- *Level variables*, also known as stocks, accumulations, or state variables, change their values by accumulating or integrating rates. This means that the values of Levels change continuously over time even when the rates are changing discontinuously.
- *Flows (or rates)* change the value of level variables. The value of a rate is not dependent on previous values of that rate; instead the Levels in a system, along with exogenous influences, determine the values of rates.
- Intermediate concepts or calculations are known as *auxiliaries* and, like rates, can change immediately in response to changes in Levels or exogenous influences.
- *Constant or initial variables* are standard variables without any internal function. In their equations numbers are used.
- *Shadow variables* refer to variables defined elsewhere in a view, in other views or in an equation. They are useful in helping to increase the clarity of a sketch. Arrows can not enter, only leave Shadow variables. They appear on a sketch surrounded by angle brackets < > and in gray.
- *Arrows* connecting the variables do not have any special function within the model. They are used only for graphic interpretation of the relation between two variables. The relation itself is stored within the variable, as internal function.

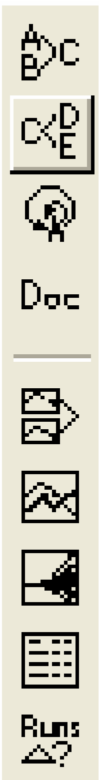
Functions

While addition, subtraction, multiplication and division are the most common components of equations, sometimes it is necessary to use different types of relationships. Vensim has a number of functions, from which IF THEN ELSE, Lookups, SUM and STEP are the most used in the developed biomass model for Borsod County.

- *IF THEN ELSE* function allows to switch between alternative formulations based on some condition. In Vensim it takes the form d = IF THEN ELSE (a,b,c), and means that d = IF a THEN b ELSE c.
- *Lookups* allow defining customized relationships between a variable and its causes. An equation can be defined with a specially-constructed function, which has a (typically nonlinear) equation. Lookups are also known as Graphical Functions, Lookup Tables, as they can be constructed as a table of numbers or as a graph.
- The Subscript function *SUM* adds together all the values for the variable with the Subscript that is marked by an exclamation point (!). Sometimes more than one Subscript range appears in an equation, so the exclamation point is used to denote the Subscript range being acted on.
- The *STEP* function - STEP({height},{stime}) - returns 0 until Time reaches {stime} and then it returns {sheight}. It is important because a step change is a clear way to get a model to show the behavior modes it can generate.

Analysis tools

Vensim provides analysis tools for investigating the model structure, displaying simulation results and analyzing and comparing simulation runs. The analysis tools show information about the Workbench Variable, either its place or value in the model, or its behavior from simulation datasets. Analysis tools are grouped into toolsets. A description of the function of the tools follows below.



- *Causes Tree* shows a tree made up from the selected variable, the variables in the model that are connected directly to the selected variable and the variables in turn that cause the directly connected variables. Angle brackets <> are used to indicate that a variable has already appear in the diagram.
- *Uses Tree* generates a tree made up from the variable, the other variables in the model that use that variable and the variables in turn that use those variables. (Angle brackets <> are used to indicate that a variable has already appear in the diagram).
- *Loops* displays a list of all feedback loops passing through the workbench variable.
- *Doc* documents the equations, definitions, units of measure, and selected values for workbench variables.
- *Causes Strip Graph* displays simple graphs in a strip, allowing to trace causality by showing the direct causes of the workbench variable.
- *Graph* generates a graph of the workbench variable with a different line for each loaded run and also for each subscript element if multiple subscripts are selected.
- *Sensitivity Graph* creates a sensitivity graph of one variable and its range of uncertainty generated from sensitivity testing.
- *Table* visualizes the value for the workbench variable at each time in a table, the same content as the graph tool with a different presentation.
- *Runs Compare* compares all Lookups and Constants in the first loaded dataset to those in the second loaded dataset.

ANNEX V. Summary description of main data sources for regional biomass modeling (metadata base)

Topic	Short name of the source	Official name of the source	Type of source	Accessi-bility	Homepage	Type of data available	Spatial level of data: HUN-GARY	NUTS1	NUTS2	NUTS3	LAU1	LAU2	Temporal level of data	Short description of the source
General	Eurostat	Statistical Office of the European Communities	Database	Yes	http://epp.eurostat.cec.eu.int	General and regional statistics, Economy and finance, Population and social conditions, Industry, trade and services, Agriculture and fisheries, External trade, Transport, Environment and energy, Science and technology	√	√	√				Mostly since 1990	The Eurostat database contains more than 100 million harmonized and comparable data in a unified form. There are 9 main statistical themes which contain social, political, economic and environmental data about the Member States and main partners of the EU. Several indicators have been developed and publications with methodological descripcion are also included.
General	KSH	Központi Statisztikai Hivatal (Hungarian Central Statistical Office)	Database	Yes	http://www.ksh.hu	Population, Society, General economic indicators, Sectors of economy, Regional statistics, International comparison	√	√	√	√	√	√	Mostly since 1990	KSH provides Stadat-system, Database for Dissemination, Interactive Thematic Maps, Population and Agri Census. Special databases are T-STAR, BP-STAR, MR-STAR, MATÉRIA, BUTÉRIA, Statistical Yearbooks, different issues and publications. In some cases historical data since 1870 are available.
General	KSH - ITM	KSH Interaktív tematikus térképek (KSH Interactive Thematic Maps)	Database	Yes	http://portal.ksh.hu/portal/page?_pageid=37,412178&_dad=portal&_schema=PORTAL	Population, Society, Economy, Environment				√	√	√	Mostly from 2000-2004	To view interactive thematic maps, an installed SVG (Scalable Vector Graphics) Viewer is required. Indicators of a given theme from the list above the map can be selected. Spatial units can also be chosen and analized.
General	KSH - Stadat	KSH Stadat-rendszer (Stadat-system)	Database	Yes	http://portal.ksh.hu/portal/page?_pageid=38,333387&_dad=portal&_schema=PORTAL	Population, Society, General economic indicators, Sectors of economy, Regional statistics, International comparison	√	√	√	√			Country data mostly 1990-2005, County data 2000-2005	The statical tables are grouped around four large topics - "Demography, Society; Economy; Regional statistics; International comparison" - which were divided into additional sub-groups. The over 300 tables provide a detailed picture about the condition of our country in the last 25 years that can be described by figures compared to our previous data system.
General	KSH - Database	KSH Tájékoztatási Adatbázis (Database for Dissemination)	Database	Yes	http://portal.ksh.hu/portal/page?_pageid=38,122433&_dad=portal&_schema=PORTAL	Population, Society, Economy, Environment	√	√	√	√			Mostly up to 2000	Access to the Dissemination Database is free. HCSO (KSH) publishes datasets of comparable time series in the database. The queries may include statistical indices such as population, along the selected dimensions such as Regions / Counties. The resulting table of the query may be used for further modifications and editing, including the location of dimensions and details. The table may be downloaded, and/or used for graphic representation. Data may be retrieved from the database along the hierarchy of statistical topics or by text. The number of topics and datasets stored on the dissemination database is continuously growing.
General	KSH - Pop Census	Népszámlálás 2001 (Population Census 2001)	Database	Yes	http://www.nepszamlalas.hu/hun/index.html (http://www.nepszamlalas.hu/eng/index.html)	Demography, employment, households, family, dwellings	√	√	√	√	√	√	2001	Official decennial censuses have been taken in Hungary since 1870; the latest one - in line with the recommendations of the United Nations and the Statistical Office of the European Union - was carried out in 2001. The Hungarian Central Statistical Office has released census information both to the experts and the general public, in electronic forms, too. The results of the 2001 census are disseminated by administrative territories (i.e. the capital, the counties and the individual localities respectively) in separate publications. The 21 books (each covering two volumes) describe on 13 thousand pages the population's demographic, educational, ethnic, religious, employment characteristics, the household and family structure, the composition and equipment of the housing stock of the capital, the counties and the country as a whole.
General	KSH - Pop Census-1	KSH	Database	Yes	http://www.nepszamlalas.hu/eng/volumes/06/05/content.html	Demography, employment, households, family, dwellings				√	√	√	2001	1. Comparison of main data by territorries and main characteristics: Summary tables on the main data of the county and the planning-statistical regions, on the changes in the most important characteristics in the demographic, employment, household, family and housing processes. 2. Retrospective data: Main data of the previous censuses according to the concepts and territorial division of the 2001 census compared to the data of the last census. 3. Detailed data: Description of the demographic, employment, household and family as well as dwellings and building situation of the county with combined tables. 4. Data by types of localities: Combination tables enabling the analysis and comparison of the data on Miskolc, with those of other cities and villages respectively. 5. Data by localities: Data partially condensed in content in territorially detailed presentation. 6. Charts: Main data on the county on colour printed charts. 7. Cartograms: Main data on the county by statistical sub-regions on coloured cartograms.
General	KSH - Pop Census-2	KSH	Database	Yes	www.nepszamlalas.hu/eng/volumes/21/tartalom.html	Demography, occupation, households, family, dwellings				√	√		2001	Upon the decision of the respective Hungarian authority (Council of Regional Development) as from January 1, 2004 a new statistical subregional system has been generated; the decision of the former authority had been approved by a Government decree. The tables – based on the 2001 census – describe the main characteristics of the subregions according to the new subregional principles.
General	BAZ Statistical Yearbooks	Borsod-Abaúj-Zemplén megye Statisztikai Évkönyve 1995 - 2004 (Statistical Yearbooks of county BAZ 1995 -2004)	Satistical Issue of KSH	Yes	Hard copies bought by KSH	National data; comparative County and regional data; County data on population, society, sectors of economy, environment; selected data on subregions, settlement groups, towns and settlements	√	√	√	√	√	√	1995-2004	Statistical Yearbooks at county level are available in hard copy and electronic format from each year since 1990, containing data on population, society, economy and environment.
General	OECD Statistics	OECD Statistics	Database	Yes	http://www.oecd.org/statsportal/0,2639,en_2825_293564_1_1_1_1_1,00.html	General and regional statistics, Economy and finance, Population, Social conditions, Health, Industry, Trade and services, Agriculture and fisheries, External trade, Transport, Environment, Energy, Science and technology	√	√						The OECD collects statistics needed for the analysis of economic and social developments by its in-house analysts, committees, working parties, and member country governments from statistical agencies and other institutions. The OECD shares the experience gained by members in compiling reliable and comparable statistics with non-member countries.
Population	Népinfo	Népinfo (Population information)	Database	Yes	www.nepinfo.hu	Population information: birth, death, emigration and immigration in the past and future	√			√			1980-2006	The Secretariat of Commission on Population Policy (NEPINFO) gives information about national and international demographic figures and about the Hungarian demographic policy.
Population	KSH NKI	KSH NKI Forecasting database	Database	Yes	http://www.nepinfo.hu/index.php?p=25&m=54	Population forecasts	√	√		√			2001-2021	Population forecast at national and county level up to 2021.
Agriculture	KSH - Agri census	Agrár idősorok és cenzusok (Agricultural long time series and censuses)	Database	Yes	http://portal.ksh.hu/portal/page?_pageid=38,569312&_dad=portal&_schema=PORTAL	Agricultural gross production value, land use, area, production and average yields of main crops, livestock, animal products, agricultural prices	√	√					1851-2000	Censuses have traditions in Hungary. The first harvest survey was conducted in 1868, the first crop production survey in 1871, the first livestock survey in 1884, the first orchard census in 1956-59 and the first vineyard census in 1961-63. Data of regular statistical data collections introduce nearly 150 years of agriculture.
Agriculture	KSH - ÁMÖ	Állami Mezőgazdasági Összeírás, 2000 (Agricultural Census, 2000)	Database	Yes	\\lbmserver\Work\RES_EUregio\Database\AMÖ_2000	The results of the last agricultural census in 2000 were summarized and published in three volumes: Agriculture in Hungary, 2000 - regional data, Livestock in Hungary , 31th March, 2000 – data by settlements, Land use in Hungary, 2000 – data by settlements. CD containing the three volumes was bought from KSH	√	√	√	√	√	√	2000	Pursuant to Act XLVI of 1999 the Hungarian Central Statistical Office (HCSO) carried out an Agricultural Census (AC 2000) in the period between the 1st and 21st of April, 2000 by the reference date of March 31, 2000. The AC 2000 was the sixth in the series of agricultural censuses. The objective of agricultural censuses is to provide a representation of the country's agriculture at the highest attainable level of accuracy The main aim of the AC 2000 was also to provide information for the accession negotiations between the European Union and Hungary. At the same time, the census joined to the world census 2000 of the Food and Agricultural Organisation (FAO) of the United Nations. The results of the AC 2000 are published in three volumes which have three parts: 1. Tables presenting the following data by municipalities, counties, regions and aggregated at national level: land use of enterprises and state farms as well as small producers and private holders. 2. Methodological notes provides detailed explanation of the definitions and concepts used in the publication. 3. Questionnaires of the Agricultural Census.
Agriculture	KSH - ÁMÖ	Magyarország mezőgazdasága a 2000. évben (Agriculture in Hungary, 2000)	Database	Yes	\\lbmserver\Work\RES_EUregio\Database\AMÖ_2000	Data on the number of farms, average size and structure of land and livestock, farm machinery and equipment, buildings and structures, agricultural production, land use and animal breeding parameters	√	√	√	√	√		2000	In the first part the publication provides data on the number of farms, average size and structure of land and livestock, farm machinery and equipment and buildings. In the second part data on agricultural production at farm- level are calculated on the basis of the value of agricultural products, distribution of production values and the specific land use and animal breeding parameters.
Agriculture	KSH - ÁMÖ	Magyarország állatállománya 2000. március 31-én (Livestock in Hungary , 31th March 2000)	Database	Yes	\\lbmserver\Work\RES_EUregio\Database\AMÖ_2000	Data about livestock of enterprises and state farms as well as small producers and private holders, structure of livestock by municipalities, number of livestock holders, rank of counties and regions	√	√	√	√	√	√	2000	The primary aim of the publication is to publish data about livestock at settlement (municipality) level in order to provide information for the local administration, professionals, scientists as well as for policy makers at national level.

Topic	Short name of the source	Official name of the source	Type of source	Accessi-bility	Homepage	Type of data available	Spatial level of data: HUN-GARY	NUTS1	NUTS2	NUTS3	LAU1	LAU2	Temporal level of data	Short description of the source
Agriculture	KSH - ÁMÖ	Földhasználat Magyarországon a 2000. évben (Land use in Hungary, 2000)	Database	Yes	\\lbmserver\Work\RES_EUregio\Database\ÁMÖ_2000	Data on size of land area used for agricultural production and on number of land users by land use categories. Data on area and population density within the administrative boundary of municipalities as well as value (expressed in Golden Crown) of arable land, orchard and vineyard are published	√	√	√	√	√	√	2000	The primary aim of the ÁMÖ publication is to publish land use data at settlement (municipality) level in order to provide information for the local administration, professionals, scientists and as well as for policy makers at national level.
Economy	Üzlet@Hálón	A magyar kereskedelmi és iparkamarák üzleti adatbázisa (Business database of the Hungarian chambers of commerce and industry)	Database	Yes	http://www.uzletahalon.hu/	Companies/organization, Masters, public service providers, Restaurants, Accommodations, Products/services, Business offers, Business properties, Investment offers, Research and development database	√			√		√	2006	The database is based on the block of Companies/organization, where the raw data can be found. This is completed with the other blocks and the detailed description of activities and offers. Detailed search is possible by counties, within the text of descriptions, as well as by the special conditions characteristic for the each blocks(eg. by activity code (NACE/TEAOR)). Data for the Companies/organizations block are: Name, Sector, Main activity, Supplementary activities, Address, Contact person, Email, Telephone, Fax, Homepage, Qualifications, Trade register number, Chamber registration number, Introducing the company/organization. The database doesn't include at all all of the companies in Hungary.
Energy	EK	Energiaközpont (Energy Center, Hungary)	Organization	Yes	www.energiaközpont.hu	Energy balances of Hungary by fuel type and sectors	√						1990-2004	Data were provided and several personal conversations were conducted with the contact person Richter Lajosné about the detailed energy balances of the country by sectors and fuel types and the methodology of data collection and calculations.
Energy	MVM	Magyar Villamos Művek Zrt. (Hungarian Electronic Association)	Organization	Yes	www.mvm.hu	Annual Reports of the company; Statistical data of the Hungarian Power System; Annual Statistical Yearbooks on Electric Energy	√						1990-2006	The primary task of MVM Zrt. is the public utility wholesale activity, which means purchasing power from the power plants and selling it to the electricity supply companies in sufficient amount to meet the actual demand of public utility consumers of the country. The other core activity of MVM is the transmission of electricity, which is performed on its own high voltage network. At the same time, MVM Rt. also carries out the necessary transmission tasks for international power trading. With the aim of providing wide-range information, MVM Rt. is producing a lot of publications and statistical yearbooks on electric energy . Statistical data inform about the Hungarian Power System, its public and autoproducer heat and/or power plants and companies.
Energy	MEH	Magyar Energia Hivatal (Hungarian Energy Office)	Organization	Yes	http://www.eh.gov.hu/	Descriptions and data series about power and heat generation and transmission, capacity and costs. Technological and system data, employment and legislative background	√						Since 1994	The Hungarian Energy Office is a national public administration body with independent powers and competence, acting under Government control and under the supervision of the Minister of Economy and Transport. The Office was established in 1994. It shall (1) issue and amend the licenses for the production of district heat in authorized power plants, the generation, distribution, trade and public utility supply of electric energy, as well as that of gas; issue establishment licenses of power plants, (2) approve the general terms of electric energy supply (3) approve the restriction lists, (4) determine the sphere of information to be disclosed, (5) prepare administrative prices of natural gas, electric energy and heat energy produced in the authorized power plants, (6) investigate customer complaints, assert the protection of consumer interests, (7) operate the Council of Energy Interest Representation, (8) cooperate in some specific tasks of the Government connected with energy saving and (9) collect, evaluate and store information about turnover and use of electricity and gas.
Energy	MAVIR	Magyar Villamosenergia-ipari Átviteli Rendszerirányító Zártkörűen Működő Részvénytársaság (MAVIR ZRt.) (Hungarian Transmission System Operator Company Ltd)	Organization	Yes	http://www.mavir.hu/	Yearly gross capacity plans and statistical data of the Hungarian power and transmission system							2003-2005	The MAVIR Hungarian Transmission System Operator Company Ltd provides reliable, efficient and secure operation of the Hungarian Power System including the required reserve capacities of generation and transmission; supervises and augments the assets of the transmission system, to perform any renewal, maintenance and development works required for a proper and reliable supply; ensures the undisturbed operation and further extension of the electricity market and access on equal terms for system users; processes the data received from the participants of electricity supply; harmonises the operation of the Hungarian Power System with the neighbouring systems; coordinates international co-operations and prepares the Network Development Strategy and putting forward proposals for the development of the generation pool.
Energy	IEA	International Energy Agency	Organization	Partially	http://www.iea.org/	Energy statistics, publications, energy policies, CO2 emissions, etc.	√							The International Energy Agency (IEA) acts as energy policy advisor to 26 member countries in their effort to ensure reliable, affordable and clean energy for their citizens. Founded during the oil crisis of 1973-74, the IEA's initial role was to co-ordinate measures in times of oil supply emergencies. Its mandate has broadened to incorporate the "Three E's" of balanced energy policy making: energy security, economic development and environmental protection. Current work focuses on climate change policies, market reform, energy technology collaboration and outreach to the rest of the world. The IEA conducts a broad programme of energy research, data compilation, publications and public dissemination of the latest energy policy analysis and recommendations on good practices. The IEA Information Centre (http://www.iea.org/Textbase/subjectqueries/index.asp) provides several data about Hungary, e.g. Energy Statistics, Oil Market Reports, Climate Change Policies and Measures, Global Renewable Energy Policies and Measures. Online Data Services (http://data.iea.org/ieastore/statslisting.asp) give an opportunity to buy more data eg. the detailed energy balance
Biomass, Biomass energy	ProBas	LCI database of the Umweltbundesamt (German EPA)	Database	Yes	http://www.probas.umweltbundesamt.de/php/	Numerous data and information about environmental relations and consequences, effects of technologies, processes and LCA	General data, without spatial specification						2000-2030	Process oriented basic data for environmental management instruments (ProBas) contains data in the themes of energy, materials, product, transport and logistics.
Forestry	ÁESZ	Állami Erdészeti Szolgálat (State Forest Service)	Organization	Limited	www.aesz.hu	Forest inventory in Hungary	√	√	√	√			Since 1990	The State Forest Service (SFS) is a governmental organization working under the direct control of the Ministry of Agriculture and Rural Development. The sphere of activities of SFS covers the total area of the country. The SFS consists of ten directorates and the headquarters. The main tasks of SFS are covering also the following fields: forest inventory on the forested area of the country (annually the forest inventory is carried out on one tenth of the total forested area.); preparation of district forest plans to be approved by the Minister of Agriculture and Rural Development and to constitute the base of the obligatory forest management plans related to the activities of forest managers; base and thematic mapping, including the interpretation of aerial photos, GPS and geodesic measurements; management of the National Forest Stand Database, updated annually and providing information services; collection of data and data processing for statistics on forestry and primary forest industry.
Forestry	ÁESZ - Miskolc	Állami Erdészeti Szolgálat Miskolci Igazgatósága (State Forest Service Miskolc Directory)	Organization	Limited		Forest inventory in BAZ County: forest stock, increment, logging, ownership, designation in details				√			1990-2005	The ÁESZ Miskolc Directory provides county level forestry data in statistical time-series form and detailed data tables about the increment, stock, cutting-age, designation and ownership of the forests.
Forestry	ÉSZAKERDŐ	ÉSZAKERDŐ ZRT. (North Hungarian Forest Share Holding Company)	Organization	Yes	www.eszakerdo.hu	Forestry data in BAZ county, mainly about logging activities, forest waste and information about the logging technology, logistics, costs, labour demand etc.				√			2000-2005	ÉSZAKERDŐ Rt. engaged in the business of forestry located in Borsod-Abaúj Zemplén county with a total of 103.000 hectares of forest area. Personal interview with the company have been conducted and time-series data were obtained mainly about the logging activities, the applied technology and related cost parameters, fuel and labour demand, etc.
Agriculture	FVM	Földművelésügyi és Vidékfejlesztési Minisztérium (Ministry of Argiculture and Rural Development)	Ministry	Yes	www.fvm.hu	The subject bioenergy gives sectoral information about legislative conditions, biodiesel, bioethanol, biogas and solid biomass. Several publications and plans are published about renewable energy resources and future development of their use from the ministry	√						Mostly after 2000	The FVM manages data and legislative information about the agriculture, forestry, rural development, animal health, plant protection and food sectors.
Agriculture	MIAU	Magyar Internetes Agrárinformatikai Újság (Medium on Internet for Agrarinformatics in Hungary)	Journal	Partially	http://miau.gau.hu	All types of analysis and data in the agricultural sector in Hungary	√	√	√	√			Since 2000	The MIAU has been established in 1998, aiming to establish internet portal for agrarian and informatic information in Hungarian language, supporting in that way the quick and overall consulting and search.
Country profiles	Earthrtends	Earth Trends Environmental Information	Database	Limited	www.earthtrends.wri.org	Country profile descripcions and yearly environmental data at country level	√						Since 1995	EarthTrends is a comprehensive online database, maintained by the World Resources Institute, that focuses on the environmental, social, and economic trends that shape the world.

ANNEX VI. Land cover and spatial distribution of BAZ County

Figure VI.1: Classification of land cover in Borsod based on [EEA,2000]

Label Level1	Label Level2	Code Level 3	Label Level3
Artificial surfaces	Urban fabric	111	Continuous urban fabric
		112	Discontinuous urban fabric
	Industrial, commercial and transport units	121	Industrial or commercial units
		122	Road and rail networks and associated land
		123	Port areas
		124	Airports
	Mine, dump and construction sites	131	Mineral extraction sites
		132	Dump sites
		133	Construction sites
	Artificial, non-agricultural vegetated areas	141	Green urban areas
		142	Sport and leisure facilities
Agricultural areas	Arable land	211	Non-irrigated arable land
		212	Permanently irrigated land
		213	Rice fields
	Permanent crops	221	Vineyards
		222	Fruit trees and berry plantations
		223	Olive groves
	Pastures	231	Pastures
	Heterogeneous agricultural areas	241	Annual crops associated with permanent crops
		242	Complex cultivation patterns
		243	Land principally occupied by agriculture, with significant areas of natural vegetation
		244	Agro-forestry areas
Forest and semi natural areas	Forests	311	Broad-leaved forest
		312	Coniferous forest
		313	Mixed forest
	Scrub and/or herbaceous vegetation associations	321	Natural grasslands
		322	Moors and heathland
		323	Sclerophyllous vegetation
		324	Transitional woodland-shrub
	Open spaces with little or no vegetation	331	Beaches, dunes, sands
		332	Bare rocks
		333	Sparsely vegetated areas
		334	Burnt areas
		335	Glaciers and perpetual snow
Wetlands	Inland wetlands	411	Inland marshes
		412	Peat bogs
	Maritime wetlands	421	Salt marshes
		422	Salines
		423	Intertidal flats
Water bodies	Inland waters	511	Water courses
		512	Water bodies
	Marine waters	521	Coastal lagoons
		522	Estuaries
		523	Sea and ocean

Figure VI.2: Levels of Corine land cover classifications [EEA,2000]

ANNEX VII. Industrial classifications at European and Hungarian level

Hungarian classification in national energy balances		**Categories of value added statistic**		**Formed categories of estimated county level energy consumption**	
NACE conformance	Branch of industry	NACE-code	Branch of industry	NACE-code	Branch of industry
		C	Mining and quarrying	C	Mining
10,11	Briquette*	CA 10-12	Mining and quarrying of energy producing materials	CA 10-12	Mining and quarrying of energy producing materials
10, 11, 12	Coal mining*				
13-14	Mining	CB 13-14	Mining and quarrying, except of energy producing materials	CB 13-14	Mining and quarrying, except of energy producing materials
		D	Manufacturing		
15-16	Food ind.	DA 15-16	Manufacture of food products, beverages and tobacco	DA 15-16	Manufacture of food products, beverages and tobacco
17-19	Textile and leather ind.	DB 17-18	Manufacture of textiles and textile products	DB, DC 17-19	Manufacture of textiles and leather
		DC 19	Manufacture of leather and leather products		
20	Wood ind.	DD 20	Manufacture of wood and wood products	DD 20	Manufacture of wood and wood products
21-22	Paper and press	DE 21-22	Manufacture of pulp, paper and paper products; publishing and printing	DE 21-22	Manufacture of pulp, paper and paper products; publishing and printing
23	Petroleum Refinement*	DF 23	Manufacture of coke, refined petroleum products and nuclear fuel	DF 23	Manufacture of coke, refined petroleum products and nuclear fuel
23	Coking*				
24	Chemistry**	DG 24	Manufacture of chemicals, chemical products and man-made fibres	DG 24	Manufacture of chemicals, chemical products and man-made fibres**
		DH 25	Manufacture of rubber and plastic products	DH 25	Manufacture of rubber and plastic products
26	Production of non-metal minerals	DI 26	Manufacture of other non-metallic mineral products	DI 26	Manufacture of other non-metallic mineral products
271, 272,2751	Iron and steel metallurgy	DJ 27-28	Manufacture of basic metals and fabricated metal products	DJ 27-28	Manufacture of basic metals and fabricated metal products
273-74, 2752,3	Non-metal metallurgy				
28-32	Machine ind.	DK 29	Manufacture of machinery and equipment n.e.c.	DK 29	Manufacture of machinery and equipment n.e.c.
		DL 30-33	Manufacture of electrical and optical equipment	DL 30-33	Manufacture of electrical and optical equipment
34, 35	Transporters and machines	DM 34-35	Manufacture of transport equipment	DM 34, 35	Manufacture of transport equipment
25, 33, 36	Other industry	DN 36,37	Manufacturing n.e.c.	DN 36	Manufacturing n.e.c. (37 neglected because of lack of data)
45	Construction	F 45	Construction	F 45	Construction
40	Electricity and heat prod*	E 40-41	Electricity, gas, steam and water supply	E 40	Electricity, gas, steam and hot water supply*

* Belongs to energy sector (own consumption)

** Without chemistry raw materials

ANNEX VIII. Forest and forestry figures in Borsod County

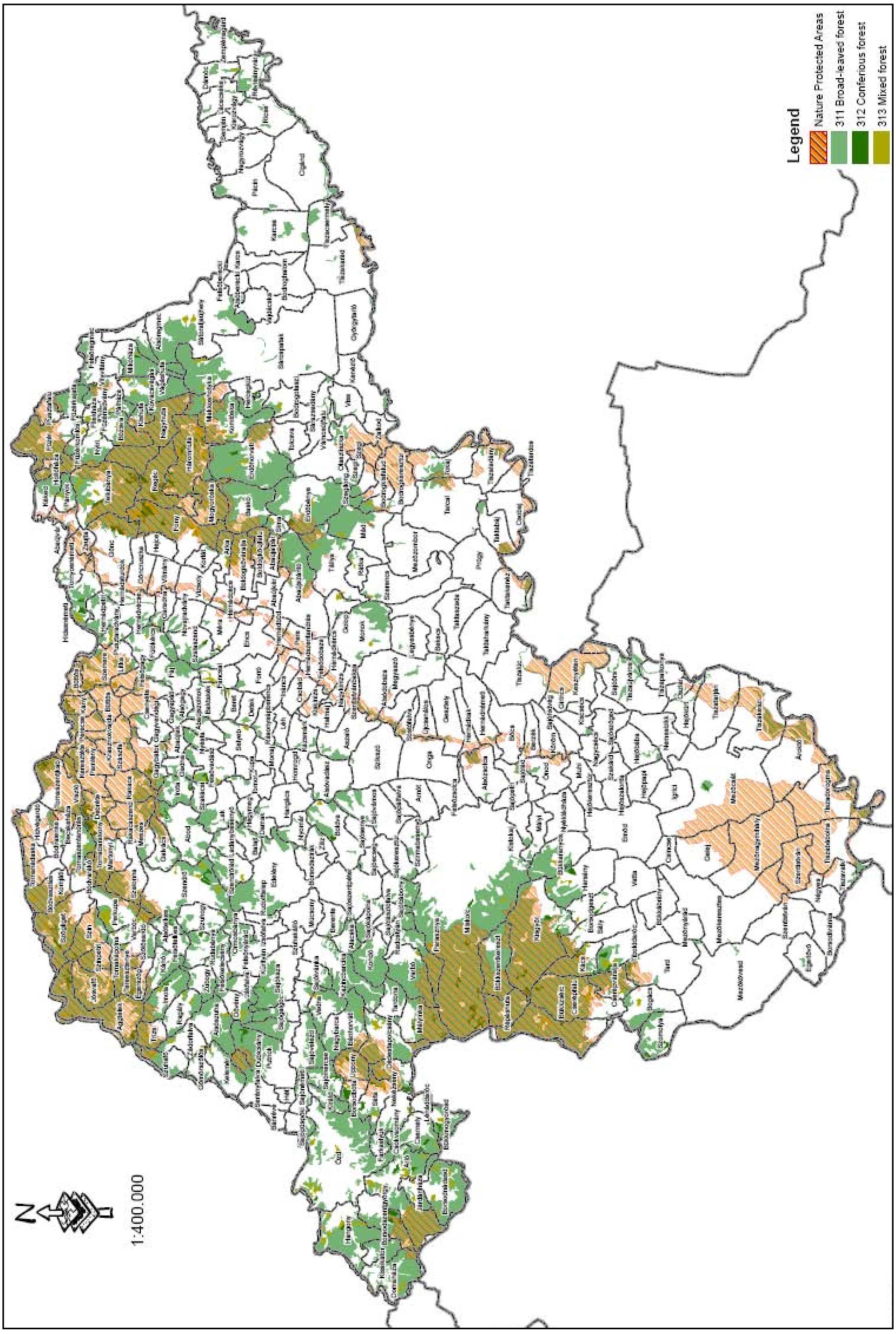


Figure VIII.1: Territorial distribution of forest areas and nature protected areas in BAZ (compiled by Lajos Dobrosi)

Table VIII.1: Selected forestry time-series data in BAZ [ÁESZ, 2006a]

Year	Forest area	Forest stock	Annual increment		Renewal	Plantation
	ha	m3	m3/a	m3/ha/a	ha/a	ha/a
2005	183,000	37,836,039	1,119,831	6.4	*	*
2004	181,197				1,765	442
2003	180,131				888	350
2002	179,522				1,008	271
2001	177,416	42,895,071	1,155,271	6.5	1,053	210
2000	177,416	42,970,395	1,154,856	6.5	847	61
1999	178,526	43,058,544	1,162,431	6.5	971	9
1998	176,570	43,090,277	1,171,248	6.6	907	277
1997	174,469	43,014,417	1,182,586	6.8	1,056	148
1996	186,000	42,589,189	1,180,541	6.4	1,038	110
1995	183,664	42,311,463	1,186,784	6.5	977	178
1994	178,911	41,671,339	1,177,393	6.6	1,010	164
1993	177,852	41,198,661	1,176,303	6.6	1,119	201
1992	177,299	40,562,735	*	*	1,081	277
1991	175,711	40,007,187	1,770,365	6.7	933	147
1990	175,662	*	*	*	1,090	211

* no data

Table VIII.2: Dynamic development of the ownership-structure of the forests in BAZ [ÁESZ, 2006a]

<table>
<tr><th>Year</th><th colspan="4">Ownership</th></tr>
<tr><td></td><td>State-owned</td><td>Public</td><td>Private</td><td>Owner not known</td></tr>
<tr><td></td><td>ha</td><td>ha</td><td>ha</td><td>ha</td></tr>
<tr><td>2005</td><td>*</td><td>*</td><td>*</td><td>*</td></tr>
<tr><td>2004</td><td>115,694</td><td>2,066</td><td>47,390</td><td>16,046</td></tr>
<tr><td>2003</td><td>115,856</td><td>2,047</td><td>46,645</td><td>15,583</td></tr>
<tr><td>2002</td><td>115,930</td><td>2,001</td><td>44,968</td><td>16,619</td></tr>
<tr><td>2001</td><td>115,630</td><td>1,822</td><td>43,528</td><td>16,436</td></tr>
<tr><td>2000</td><td>115,630</td><td>1,822</td><td>43,528</td><td>16,436</td></tr>
<tr><td>1999</td><td>115,715</td><td>1,937</td><td>41,540</td><td>19,334</td></tr>
<tr><td>1998</td><td>113,760</td><td>1,506</td><td>39,942</td><td>21,362</td></tr>
<tr><td>1997</td><td>112,158</td><td>1,133</td><td>45,916</td><td>15,262</td></tr>
<tr><td>1996</td><td>111,408</td><td>1,704</td><td>55,823</td><td>17,065</td></tr>
<tr><td>1995</td><td>114,032</td><td>1,244</td><td>50,647</td><td>17,741</td></tr>
<tr><td>1994</td><td>123,330</td><td colspan="2">55,581</td><td>*</td></tr>
<tr><td>1993</td><td>127,051</td><td>1,451</td><td>49,350</td><td>*</td></tr>
<tr><td>1992</td><td>126,858</td><td>1,384</td><td>49,056</td><td>*</td></tr>
<tr><td>1991</td><td>126,595</td><td>1,154</td><td>47,962</td><td>*</td></tr>
<tr><td>1990</td><td>126,525</td><td>1,154</td><td>47,983</td><td>*</td></tr>
</table>

* no data

Table VIII.3: Forest stock in 2001 [ÁESZ, 2002]

		Unit	Hungary	Borsod County
Stock of forests for timber production	total	thousand m3	205,490	21,677
	average stock per forest land	m3/ha	175	211
Stock of forests with specific designation	total	thousand m3	120,920	21,294
	average stock per forest land	m3/ha	197	235
Stock of total forests	total	thousand m3	326,410	42,971
	average stock per forest land	m3/ha	183	222

Table VIII.4: Distribution of forest land by tree species in 2001 [ÁESZ, 2002]

Name	Unit	Hungary	Borsod County
oak	%	21	39
	thousand ha	355.2	72.1
turkey oak	%	11.4	12.4
	thousand ha	192.4	22.9
beech	%	6.2	14.1
	thousand ha	104.1	26
hornbeam	%	5.7	10.6
	thousand ha	97.2	19.7
robinia	%	21.6	6.8
	thousand ha	364.4	12.6
other hard broad-leaved		4.6	3
	thousand ha	78.4	5.5
poplar	%	9.7	3.9
	thousand ha	63.8	7.2
willow		1.3	0.9
	thousand ha	22.7	1.7
alder	%	2.9	0.3
	thousand ha	48.4	0.6
other soft board-leaved	%	1.4	0.5
	thousand ha	23.5	0.9
conifers	%	14.2	8.5
	thousand ha	239.1	15.8
Total	%	100	100
	thousand ha	1689.4	185

Table VIII.5: Total gross logging of forests in 2000 [ÁESZ, 2002]

	Unit	Hungary	Borsod County
endcut	thousand ha	21.0	1.6
	thousand m3 of gross woodbulk	5,021	391
thinning 1	thousand ha	17.8	1.3
	thousand m3 of gross woodbulk	745	43
thinning 2	thousand ha	24.7	1.7
	thousand m3 of gross woodbulk	687	51
clearance	thousand ha	30.0	2.4
	thousand m3 of gross woodbulk	346	33
sanitary	thousand m3 of gross woodbulk	427	58
other	thousand m3 of gross woodbulk	61	7
total	thousand m3 of gross woodbulk	7,287	583

ANNEX IX. Short rotation coppice (SCR) - Poplar

Planted poplar

Poplar 2 months

Poplar 14 months

Motor-manual harvesting of poplar

Chipper-harvester

Source: [Marosvölgyi, 2006], [Braun, 2006]

ANNEX X. Energy production of Borsod County

Table X.1: Power plants in Borsod County

Size	Name	Location	Status	In the Power System	Type	Fuel type	Production From	Until	Data available from
Big plants	Tisza II	Tiszaújváros	public	Yes		Gas+oil	1972-1978		1992-2006
	Tiszapalk.	Tiszaújváros	public	Yes		Coal+biomass	1952-1959		1992-2006
	Borsod	Kazincbarcika	public	Yes		Coal+biomass	1951-1957		1992-2006
	Sajószöged GT	Sajószöged	public	Yes	GT	Oil	1998		1992-2006
Small plants	Ózdi Kohászati Művek	Ózd	industrial	Yes			*	1994	1992-1996
	Északmagyarországi Vegyiművek		industrial	No			*	*	
	DIMAG Rt., Diósgyőri Acélművek Kft.	Miskolc	industrial	Yes			*	1996	1992-1996
	Miskolci Tatár u. Erőmű	Miskolc	industrial	No	gasmotor	Gas	2003		2003
	Szerencsi Cukorgyár	Szerencs	industrial	No	steamturbine	Oil	*		1998, 2002
	Kazinc-Therm Fűtőerőmű	Kazincbarcika	industrial	No	gasmotor	Gas	2002		2002
	Tiszaújvárosi Fűtőerőmű	Tiszaújváros	industrial	No	gasmotor	Gas	2002		2002
	Kesznyéteni Vízerőmű	Kesznyéten	public	Yes	water turbine	Water	1943		1992-2003
	Ózdi Távhő	Ózd	industrial	No	gasmotor	Gas	*		2002
	Mályi Téglagyár	Mály	industrial	No	gasmotor	Gas	*	*	2002
	Sárospatak Távhő	Sárospatak	industrial	No	gasmotor	Gas	*		2002
	Felsődobszai Vízerőmű	Felsödobsza	public	Yes	water turbine	Water	1912		1992-2003
	BAZ Megyei Kórház	Miskolc	industrial	No	gasmotor	Gas	*	*	2002
	Gibárti Vízerőmű	Gibárt	public	Yes	water turbine	Water	1903		1992-2003
	Hernádvécsei Vízerőmű	Hernádvécse	public	Yes	water turbine	Water	*		2002-2003
	Forrói Vízerőmű	Forró	public	Yes	water turbine	Water	*		2002-2004
	Felsőmérai Vízerőmű	Felsöméra	public	Yes	water turbine	Water	*		2002-2005
	Serényfalvi Téglagyár	Serényfalva	industrial	No	gasmotor	Gas	*	*	2003
	Diósgyöri Fűtőerőmű	Miskolc	industrial	No	gasmotor	Gas	2003		2003
	Miskolci Kis Fűtőerőmű	Miskolc-Bulgárföld	industrial	No	gasmotor	Gas	2003		2003
	BorsodChem Rt.	Kazincbarcika	industrial	No			*	*	1998
	BC–Erőmű	Kazincbarcika	industrial	Yes	CCGT	Gas	2001		2002
	Tiszai Vegyi Kombinát	Tiszaújváros	industrial	No			*	*	1998
	TVK Erőmű	Tiszaújváros	industrial	No	CCGT	Gas	2005		
	Bükkaranyos	Bükkaranyos			windturbine	Wind	2004		2004

plants closed up in the 1990s

assumed to produce power between 1990-2000

* no data

Table X.2: Realized power from the heat and/or power plants between 1990-2004 in Borsod County

Power fed into the national grid, GWh

Size	Name	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Big plants	Tisza II	1,722	2,296	2,512	2,887	3,020	2,875	3,103	3,314	3,242	3,203	2,687	2,922	2,489	2,426	1,525
	Tiszapalk.	849	804	807	683	567	554	545	440	695	660	389	466	395	477	365
	Borsod	452	445	507	348	332	388	404	430	397	393	382	375	343	282	362
	Sajószöged GT	0	0	0	0	0	0	0	0	6	3	3	3	1	3	1
BIG total		*3,024*	*3,545*	*3,826*	*3,919*	*3,919*	*3,816*	*4,052*	*4,184*	*4,340*	*4,259*	*3,462*	*3,765*	*3,228*	*3,188*	*2,253*
Small plants	Ózdi Kohászati Művek	7.3	6.3	3.9	3.4	2.7	0	0	0	0	0	0	0	0	0	0
	Északmagyarországi Vegyiművek															
	DIMAG Rt., Diósgyőri Acélművek Kft.	7.1	6.6	7.0	3.5	4.6	4.2	4.3	0	0	0	0	0	0	0	0
	Miskolci Tatár u. Erőmű	0	0	0	0	0	0	0	0	0	0	0	0	0	63.2	126.4
	Szerencsi Cukorgyár	11	11	11	11	11	11	11	11	11	11	11	11	11	11.0	11.0
	Kazinc-Therm Fűtőerőmű	0	0	0	0	0	0	0	0	0	0	0	0	14	56.0	56.0
	Tiszaújvárosi Fűtőerőmű	0	0	0	0	0	0	0	0	0	0	0	0	7	28.0	28.0
	Kesznyéteni Vízerőmű	16.5	16.5	14.1	9.7	14.4	16.8	20.6	19.0	17.3	16.2	16.2	16.4	13.8	23.2	16.5
	Ózdi Távhő											6.8	6.8	6.8	6.8	6.8
	Mályi Téglagyár												4.9	4.9	4.9	4.9
	Sárospatak Távhő												4.2	4.2	4.2	4.2
	Felsődobszai Vízerőmű	2.4	2.4	2.7	2.1	2.5	2.4	1.5	2.1	2.8	2.9	2.5	2.4	2.5	2.2	2.4
	BAZ Megyei Kórház															
	Gibárti Vízerőmű	2.8	2.8	2.5	2.0	2.9	2.9	3.3	3.2	2.9	2.8	2.5	2.8	3.0	2.5	2.8
	Hernádvécsei Vízerőmű															
	Forrói Vízerőmű															
	Felsőmérai Vízerőmű															
	Serényfalvi Téglagyár															
	Diósgyőri Fűtőerőmű	0	0	0	0	0	0	0	0	0	0	0	0	0	11.1	22.1
	Miskolci Kis Fűtőerőmű	0	0	0	0	0	0	0	0	0	0	0	0	0	2.8	5.5
	BorsodChem Rt., BC–Erőmű	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	183.3	314.2	314.2	314.2
	Tiszai Vegyi Kombinát	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	0	0	0	0
SMALL total		*68*	*66*	*62*	*53*	*59*	*58*	*62*	*56*	*55*	*54*	*60*	*232*	*381*	*530*	*601*
TOTAL GWh		***3,092***	***3,612***	***3,888***	***3,971***	***3,977***	***3,875***	***4,113***	***4,240***	***4,395***	***4,313***	***3,522***	***3,997***	***3,609***	***3,718***	***2,854***
TOTAL TJ		***11,131***	***13,002***	***13,998***	***14,297***	***14,319***	***13,948***	***14,807***	***15,265***	***15,821***	***15,527***	***12,678***	***14,388***	***12,994***	***13,385***	***10,274***

estimated data

Table X.3: Example of Vensim input data-series

Realized electricity (TJ) from											
SUM		**Solid fuels**		**Oil Products**		**Natural gas**		**Wind and water**		**Firewood**	
1990	11131	**1990**	4221	**1990**	2519	**1990**	4312	**1990**	78	**1990**	0
1991	13002	**1991**	4047	**1991**	3343	**1991**	5534	**1991**	78	**1991**	0
1992	13998	**1992**	4325	**1992**	2700	**1992**	6903	**1992**	70	**1992**	0
1993	14297	**1993**	3303	**1993**	3284	**1993**	7661	**1993**	50	**1993**	0
1994	14319	**1994**	2838	**1994**	4424	**1994**	6985	**1994**	71	**1994**	0
1995	13948	**1995**	2932	**1995**	3867	**1995**	7070	**1995**	80	**1995**	0
1996	14807	**1996**	2966	**1996**	3538	**1996**	8212	**1996**	91	**1996**	0
1997	15265	**1997**	2698	**1997**	4979	**1997**	7501	**1997**	87	**1997**	0
1998	15821	**1998**	3570	**1998**	4454	**1998**	7714	**1998**	83	**1998**	0
1999	15527	**1999**	3364	**1999**	4642	**1999**	7442	**1999**	79	**1999**	0
2000	12678	**2000**	2483	**2000**	5213	**2000**	4906	**2000**	76	**2000**	0
2001	14388	**2001**	2693	**2001**	4249	**2001**	7368	**2001**	78	**2001**	0
2002	12994	**2002**	2400	**2002**	6392	**2002**	4084	**2002**	70	**2002**	49
2003	13385	**2003**	2271	**2003**	3502	**2003**	7349	**2003**	100	**2003**	163
2004	10274	**2004**	1546	**2004**	1465	**2004**	6253	**2004**	78	**2004**	931
2005	10274	**2005**	1546	**2005**	1465	**2005**	6253	**2005**	78	**2005**	931
2006	10274	**2006**	1546	**2006**	1465	**2006**	6253	**2006**	78	**2006**	931
2007	10274	**2007**	1546	**2007**	1465	**2007**	6253	**2007**	78	**2007**	931
2008	10274	**2008**	1546	**2008**	1465	**2008**	6253	**2008**	78	**2008**	931
2009	10274	**2009**	1546	**2009**	1465	**2009**	6253	**2009**	78	**2009**	931
2010	10274	**2010**	1546	**2010**	1465	**2010**	6253	**2010**	78	**2010**	931
2011	10274	**2011**	1546	**2011**	1465	**2011**	6253	**2011**	78	**2011**	931
2012	10274	**2012**	1546	**2012**	1465	**2012**	6253	**2012**	78	**2012**	931
2013	8961	**2013**	524	**2013**	1465	**2013**	6171	**2013**	78	**2013**	723
2014	7659	**2014**	0	**2014**	1465	**2014**	6115	**2014**	78	**2014**	0
2015	7659	**2015**	0	**2015**	1465	**2015**	6115	**2015**	78	**2015**	0
2016	7659	**2016**	0	**2016**	1465	**2016**	6115	**2016**	78	**2016**	0
2017	7659	**2017**	0	**2017**	1465	**2017**	6115	**2017**	78	**2017**	0
2018	7659	**2018**	0	**2018**	1465	**2018**	6115	**2018**	78	**2018**	0
2019	7659	**2019**	0	**2019**	1465	**2019**	6115	**2019**	78	**2019**	0
2020	7659	**2020**	0	**2020**	1465	**2020**	6115	**2020**	78	**2020**	0

estimated data

Table X.4: Distribution of fuel consumption by fuel types and energy plants (detail)

Total fuel consumption, TJ

Size	Name	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	Tisza II	17,092	22,790	24,828	28,636	29,597	28,465	30,542	32,662	32,300	31,581	26,493	28,994	24,859	24,196	15,306
Big	Tiszapalk.	16,581	15,647	14,153	12,369	10,576	10,136	10,435	8,224	11,743	11,277	7,915	8,324	7,285	8,222	6,870
plants	Borsod	13,157	12,812	11,870	9,428	8,847	9,875	9,851	10,515	9,548	9,704	10,197	8,800	7,667	6,777	8,180
	Sajószöged GT	0	0	0	0	0	0	0	0	69	34	43	35	11	39	17
BIG total		*46,830*	*51,249*	*50,851*	*50,434*	*49,020*	*48,476*	*50,828*	*51,401*	*53,660*	*52,596*	*44,648*	*46,154*	*39,822*	*39,234*	*30,373*
SMALLtotal		*1,256*	*1,228*	*1,183*	*1,014*	*1,099*	*1,074*	*1,108*	*969*	*957*	*945*	*1,010*	*3,000*	*4,560*	*5,980*	*6,601*
TOTAL		48,086	52,476	52,035	51,447	50,119	49,549	51,935	52,370	54,617	53,542	45,658	49,155	44,382	45,214	36,974

Coal consumption, TJ

Size	Name	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	Tisza II															
Big	Tiszapalk.	14,753	13,921	12,801	10,987	9,093	8,672	8,937	7,110	10,784	9,997	7,061	7,395	6,754	7,304	5,349
plants	Borsod	11,712	11,405	10,785	8,226	7,825	8,570	8,603	9,017	8,497	8,621	9,144	7,833	6,708	4,945	4,844
	Sajószöged GT															
BIG total		*26,466*	*25,326*	*23,586*	*19,212*	*16,918*	*17,242*	*17,540*	*16,128*	*19,281*	*18,618*	*16,205*	*15,229*	*13,462*	*12,249*	*10,193*
SMALLtotal		*313*	*285*	*263*	*151*	*174*	*126*	*127*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
TOTAL		26,779	25,612	23,849	19,363	17,092	17,369	17,667	16,128	19,281	18,618	16,205	15,229	13,462	12,249	10,193

Gas consumption, TJ

Size	Name	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
	Tisza II	10,272	13,696	17,538	19,711	17,668	17,955	20,987	19,143	20,150	19,013	12,363	17,424	7,148	14,541	11,247
Big	Tiszapalk.	1,805	1,703	1,333	1,364	1,466	1,439	1,480	1,109	946	1,268	849	906	529	895	432
plants	Borsod	1,440	1,403	1,080	1,199	1,021	1,297	1,245	1,493	1,050	1,078	1,051	963	648	742	510
	Sajószöged GT															
BIG total		*13,517*	*16,802*	*19,951*	*22,274*	*20,155*	*20,692*	*23,712*	*21,745*	*22,145*	*21,358*	*14,263*	*19,294*	*8,325*	*16,178*	*12,189*
SMALLtotal		*362*	*362*	*362*	*362*	*362*	*362*	*362*	*362*	*362*	*362*	*434*	*2,421*	*4,352*	*5,684*	*6,369*
TOTAL		13,879	17,164	20,313	22,636	20,517	21,054	24,074	22,107	22,507	21,720	14,697	21,714	12,677	21,862	18,558

estimated data

ANNEX XI. Potential analysis of the forest sector in Borsod County (year 2004)

INPUT	Total forest land	Gross increment		
	[ha]	[m³/ha/year]	[m³/year]	[TJ/year]
	181,197	6	1,159,661	8,697

Available potential	Heating value total	
	[MWh/year]	[TJ/year]
	2,415,573	8,697

Gross logging [m³/year]	End cut		Thinning1		Thinning2		Clearance		Sanitary and		Total	
	gross	net	gross	net	gross	net	gross	net	gross	net	gross	net
	342,826	285,688	37,871	26,299	47,680	38,764	19,232	4,040	30,154	22,336	477,763	377,128

Economically collectable potential [m³/year]	End cut		Thinning	Clearance	Sanitary	Total
	net mass	residues				
	257,120	25,712	59,886	8,654	15,479	366,851

of which firewood [m³/year]	End cut		Thinning1		Thinning2		Clearance		Sanitary and		Total		
	gross	net	gross	net	gross	net	gross	net	gross	net	gross	net	*[TJ/year]*
	185,145	167,428	37,871	26,299	38,144	31,612	19,232	4,040	30,154	22,336	310,546	251,716	1,888

of which residues [m³/year]	End cut	Thinning1	Thinning2	Clearance	Sanitary and other	Total
	28,569	26,299	3,004	4,040	22,336	84,249

of which collected by residential	Thinning1	Clearance	Sanitary and other	Total
	26,299	4,040	22,336	52,676

Additional potential for energetic purpose	Additional extractable wood		Heating value total	
	gross	net		
	[m³/year]		[MWh/year]	[TJ/year]
	713,471	594,559	1,238,467	4,459

ANNEX XII. Energy consumption of Borsod County

Table XII.1: Final consumption of selected fuels by the households sector in BAZ (1993-2004)

Final energy consumption of households in BAZ

Denomination	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Electricity												
Electricity consumer, piece	341,304	343,268	345,544	346,971	348,507	349,868	349,873	349,178	349,114	349,847	351,812	352,262
of which: hh consumer, piece	304,550	305,753	306,845	307,752	308,710	309,289	308,202	326,450	326,515	322,731	324,413	312,911
Supplied electricity, MWh	3,017,233	3,069,274	3,174,573	3,070,352	3,145,333	3,145,931	3,112,717	3,189,446	3,186,043	3,146,216	3,055,367	2,985,747
to HH, MWh	620,459	608,235	618,208	619,453	591,759	576,601	586,929	588,747	578,168	562,143	591,344	607,627
Consumption of electricity per one HH consumer, kWh	2,043	1,993	2,018	2,016	1,920	1,866	1,901	1,855	1,771	1,732	1,828	1,907
Electricity consumption of hh in BAZ, TJ	2,234	2,190	2,226	2,230	2,130	2,076	2,113	2,119	2,081	2,024	2,129	2,187
Piped gas												
Settlements with piped gas, piece	63	103	153	185	267	269	274	282	285	285	291	292
Piped gas consumer, piece	114,783	127,571	137,982	147,730	163,224	169,859	175,757	181,999	187,586	193,261	199,881	205,383
of which hh consumer, piece	111,721	123,881	133,736	143,368	157,583	163,380	168,567	174,041	178,786	184,001	190,271	195,082
hh consumer in % of the dwelling stock, %	40.4%	44.6%	48.0%	51.3%	56.1%	57.9%	59.6%	62.3%	63.9%	65.6%	67.6%	69.1%
Sold gas, 1000m3	300,995	315,946	342,803	379,713	406,805	386,930	391,082	387,733	402,133	442,565	530,896	519,499
to HH, 1000m3	116,843	138,848	163,402	187,292	204,244	192,725	220,927	213,166	220,227	247,838	276,080	265,670
Consumption of gas per one HH consumer, m3	1,117	1,179	1,269	1,352	1,357	1,201	1,331	1,244	1,248	1,366	1,475	1,379
Piped gas consumption of hh in BAZ, TJ	3,973	4,721	5,556	6,368	6,944	6,553	7,512	7,248	7,488	8,426	9,387	9,033
District heat and warm water												
Settlements with district heat and warm water network, piece	12	12	11	11	10	10	10	11	8	8	8	7
Dwellings connected to district heat, piece	54,599	54,607	54,553	54,682	54,396	54,475	54,180	54,064	53,734	53,470	53,420	53,018
Dwellings connected to district heat, %	19.7%	19.7%	19.6%	19.6%	19.4%	19.3%	19.2%	19.4%	19.2%	19.1%	19.0%	18.8%
Dwellings connected to warm water network, piece	49,233	49,325	49,276	49,298	49,205	49,305	48,233	48,934	48,652	48,397	48,356	47,930
Dwellings connected to warm water network, %	17.8%	17.8%	17.7%	17.6%	17.5%	17.5%	17.1%	17.5%	17.4%	17.3%	17.2%	17.0%

calculated data

source: [KSH, 2004b]

Table XII.2: Calculation process of the district heat consumption in the households sector in BAZ

District heat consumption of households

HUNGARY*	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Derived heat (district heat), TJ	34,758	36,333	33,923	31,500	27,537	33,690	34,146	33,426	31,687	31,687	28,081	31,297	28,085	30,215	28,188

* source: Energy Centre, Hungary [EK, 2006a]

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Number of dwellings connected to district heating in Hungary**	644,556					649,581			649,241	649,713	648,679	647,116	648,363	649,443	
Number of dwellings connected to district heating in BAZ***	54,266			54,599	54,607	54,553	54,682	54,396	54,475	54,180	54,064	53,734	53,470	53,420	53,018
% BAZ/HU	*8.4%*	*8.4%*	*8.4%*	*8.4%*	*8.4%*	*8.4%*	*8.4%*	*8.4%*	*8.4%*	*8.3%*	*8.3%*	*8.3%*	*8.2%*	*8.2%*	*8.2%*

** source: A kommunális ellátás fontosabb adatai 2003 [KSH, 2004c]

***source: Statistical Yearbooks of BAZ [KSH, 2004b]

BAZ	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Derived heat (district heat), TJ	2,926	3,052	2,850	2,646	2,313	2,829	2,868	2,808	2,659	2,642	2,340	2,599	2,316	2,485	2,311

estimated data

Table XII.3: Estimated figures of the final energy consumption of selected industrial sub-sectors by fuel types in BAZ

Final energy consumption of industry in BAZ
estimated from country level with VA rate

Nace Code	NAME	Fuel Type	Unit	1998	1999	2000	2001	2002	2003
DG 24	Chemistry*	*Total*	*TJ*	*8,391*	*7,661*	*7,943*	*6,297*	*6,552*	*5,081*
		Total control	*TJ*	*8,391*	*7,661*	*7,943*	*6,297*	*6,552*	*5,081*
		Solid fuels	TJ	3	2	2	2	1	0
		Oil Products	TJ	2,903	2,601	3,096	2,204	2,342	1,674
		Natural gas	TJ	2,525	2,517	2,322	1,830	1,837	1,233
		Electricity TJ	TJ	1,854	1,487	1,514	1,290	1,334	1,166
		Derived heat (district heat)	TJ	1,106	1,054	1,009	971	1,038	1,009
		RES	TJ	0	0	0	0	0	0
		Firewood	TJ	0	0	0	0	0	0
DH 25	Manufacture of rubber and plastic products	*Total*	*TJ*	*86*	*50*	*58*	*73*	*47*	*43*
		Total control	*TJ*	*86*	*50*	*58*	*73*	*47*	*43*
		Solid fuels	TJ	1	1	0	0	0	0
		Oil Products	TJ	3	1	1	1	1	4
		Natural gas	TJ	42	20	20	28	19	12
		Electricity TJ	TJ	20	14	22	31	25	26
		Derived heat (district heat)	TJ	20	15	14	12	2	1
		RES	TJ	0	0	0	0	0	0
		Firewood	TJ	0	0	0	0	0	0
DI 26	Production of non-metal minerals	*Total*	*TJ*	*1,974*	*1,550*	*1,252*	*1,662*	*1,743*	*1,643*
		Total control	*TJ*	*1,974*	*1,550*	*1,252*	*1,662*	*1,743*	*1,643*
		Solid fuels	TJ	247	203	205	263	226	149
		Oil Products	TJ	451	371	192	192	275	318
		Natural gas	TJ	1,024	772	679	961	993	906
		Electricity TJ	TJ	223	181	155	214	230	229
		Derived heat (district heat)	TJ	28	23	21	33	18	41
		RES	TJ	0	0	0	0	0	0
		Firewood	TJ	0	0	0	0	0	0
DJ 27-28	Manufacture of basic metals and fabricated metal products	*Total*	*TJ*	*2,822*	*3,369*	*2,592*	*2,987*	*2,473*	*2,502*
		Total control	*TJ*	*2,822*	*3,369*	*2,592*	*2,987*	*2,473*	*2,502*
		Solid fuels	TJ	1,424	1,782	1,275	1,485	1,095	1,206
		Oil Products	TJ	20	14	10	10	7	7
		Natural gas	TJ	718	825	685	894	747	673
		Electricity TJ	TJ	413	475	402	349	422	409
		Derived heat (district heat)	TJ	247	273	221	248	202	208
		RES	TJ	0	0	0	0	0	0
		Firewood	TJ	0	0	0	0	0	0

Table XII.4: Share of value added (VA) of the industrial sub-sectors in BAZ in comparison to Hungary

Nace Code	Branche of industry	1998	1999	2000	2001	2002	2003
C	*Mining and quarrying*	*15%*	*20%*	*25%*	*12%*	*10%*	*8%*
CA 10-12	Mining and quarrying of energy producing materials	14%	25%	41%	7%	4%	3%
CB 13-14	Mining and quarrying, except of energy producing materials	16%	16%	14%	13%	12%	11%
D	*Manufacturing*	*6%*	*6%*	*5%*	*6%*	*5%*	*5%*
DA 15-16	Manufacture of food products, beverages and tobacco	5%	6%	5%	5%	5%	6%
DB 17-18	Manufacture of textiles and textile products	5%	5%	5%	5%	5%	4%
DC 19	Manufacture of leather and leather products	2%	2%	2%	3%	3%	2%
DD 20	Manufacture of wood and wood products	2%	2%	2%	3%	3%	2%
DE 21-22	Manufacture of pulp, paper and paper products; publishing and printing	2%	1%	2%	2%	2%	2%
DF 23	Manufacture of coke, refined petroleum products	5%	5%	4%	5%	4%	4%
DG 24	Manufacture of chemicals, chemical products and man-made fibres	25%	23%	23%	19%	20%	17%
DH 25	Manufacture of rubber and plastic products	7%	7%	8%	8%	8%	7%
DI 26	Manufacture of other non-metallic mineral products	7%	6%	5%	6%	7%	7%
DJ 27-28	Manufacture of basic metals and fabricated metal products	7%	9%	7%	8%	6%	6%
DK 29	Manufacture of machinery and equipment n.e.c.	4%	5%	4%	4%	4%	4%
DL 30-33	Manufacture of electrical and optical equipment	1%	1%	1%	2%	2%	2%
DM 34-35	Manufacture of transport equipment	2%	1%	1%	1%	2%	2%
DN 36,37	Manufacturing n.e.c.	4%	3%	4%	4%	3%	3%
F 45	*Construction*	*5%*	*5%*	*5%*	*5%*	*4%*	*5%*
C+D+F	**Total**	**6%**	**6%**	**5%**	**5%**	**5%**	**5%**
E 40-41	*Electricity, gas and water supply*	*10%*	*10%*	*10%*	*11%*	*10%*	*9%*
20+25+30-33+36+37+45	Other non-classified industries	3%	3%	3%	4%	4%	4%
DB+DC	Textile, leather and clothing industry	4%	4%	4%	4%	4%	4%
DK-DM	Engineering and other metal industry	2%	2%	2%	2%	2%	3%

Table XII.4: Estimated historical time-series and future prognosis of the transport sector's energy consumption in BAZ

Final energy consumption of transport in BAZ

TOTAL		**1990**	**1995**	**2000**	**2001**	**2002**	**2003**	**2004**	**2010**	**2015**	**2020**
Total	*TJ*	*6,827*	*5,179*	*6,538*	*6,733*	*7,127*	*7,302*	*8,061*	*8,065*	*8,613*	*9,133*
Solid fuels	TJ	3	1	1	1	1	1	0	0	0	0
Oil products	TJ	6,593	4,962	6,321	6,513	6,910	7,078	7,828	7,853	8,403	8,923
Natural gas	TJ	0	2	4	4	4	5	4	4	5	5
Electricity	TJ	230	214	212	216	212	219	229	207	206	204
Rail transport											
Total	*TJ*	*637*	*462*	*411*	*395*	*383*	*387*	*392*			
Solid fuels	TJ	0	0	0	0	0	0	0			
Oil products	TJ	406	247	199	180	171	168	163			
Natural gas	TJ	0	0	0	0	0	0	0			
Electricity	TJ	230	214	212	216	212	219	229			
Road transport											
Total	*TJ*	*6,191*	*4,717*	*6,127*	*6,337*	*6,744*	*6,915*	*7,669*			
Solid fuels	TJ	3	1	1	1	1	1	0			
Oil products	TJ	6,187	4,715	6,122	6,333	6,739	6,910	7,665	7,667		8,711
Natural gas	TJ	0	2	4	4	4	5	4			
Electricity	TJ	0	0	0	0	0	0	0			

Future changes in oil products consumption in the road transport sector

Period	**2003-2010**	**2010-2020**
Total change	10.95%	13.62%
Av. change per year	1.56%	1.36%

source: GKM - Ministry for Economy and Transport [Giber, 2005]

ANNEX XIII. Selected maps of Borsod County

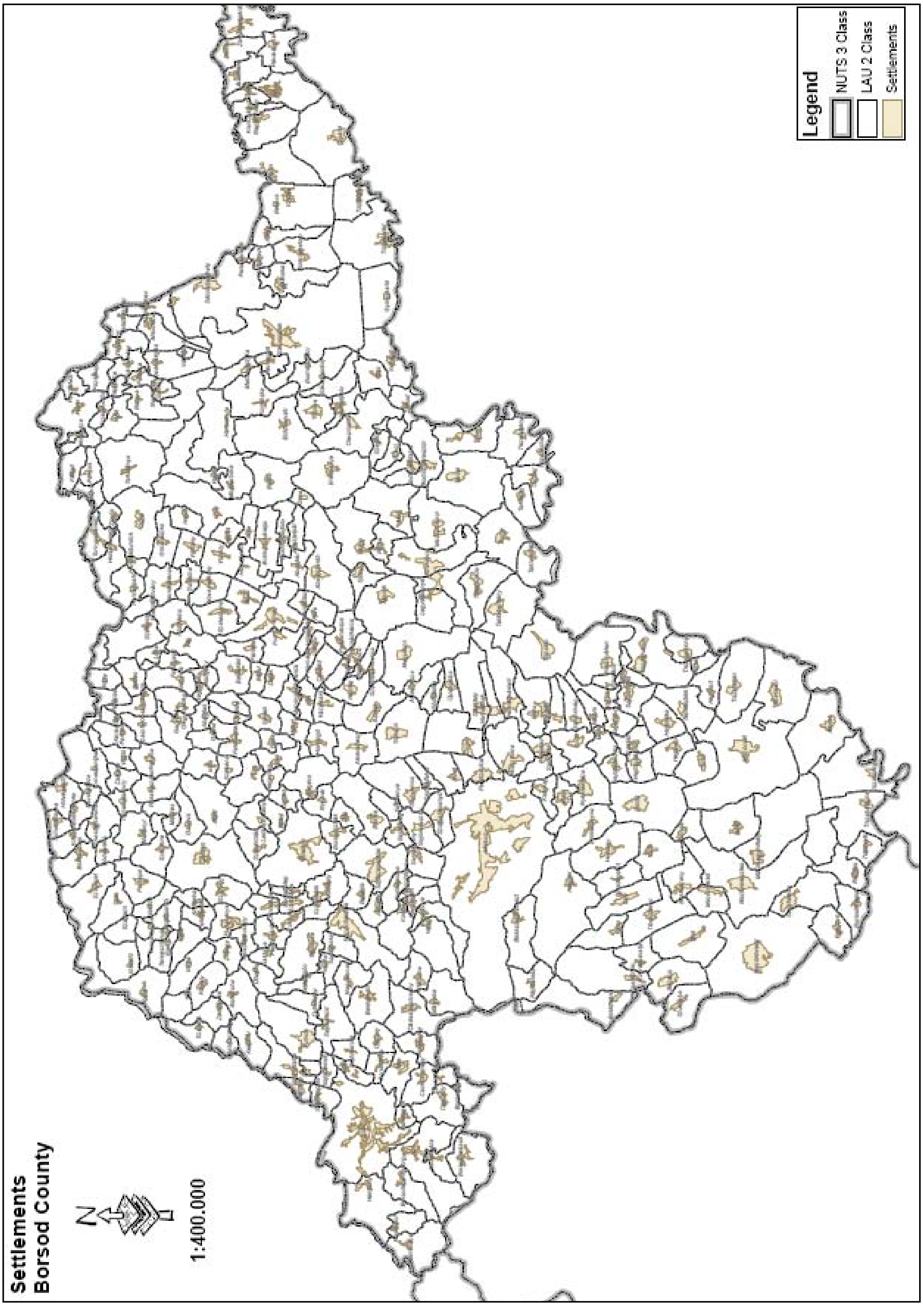


Figure XIII.1: Settlement structure of BAZ (compiled by Lajos Dobrosi)

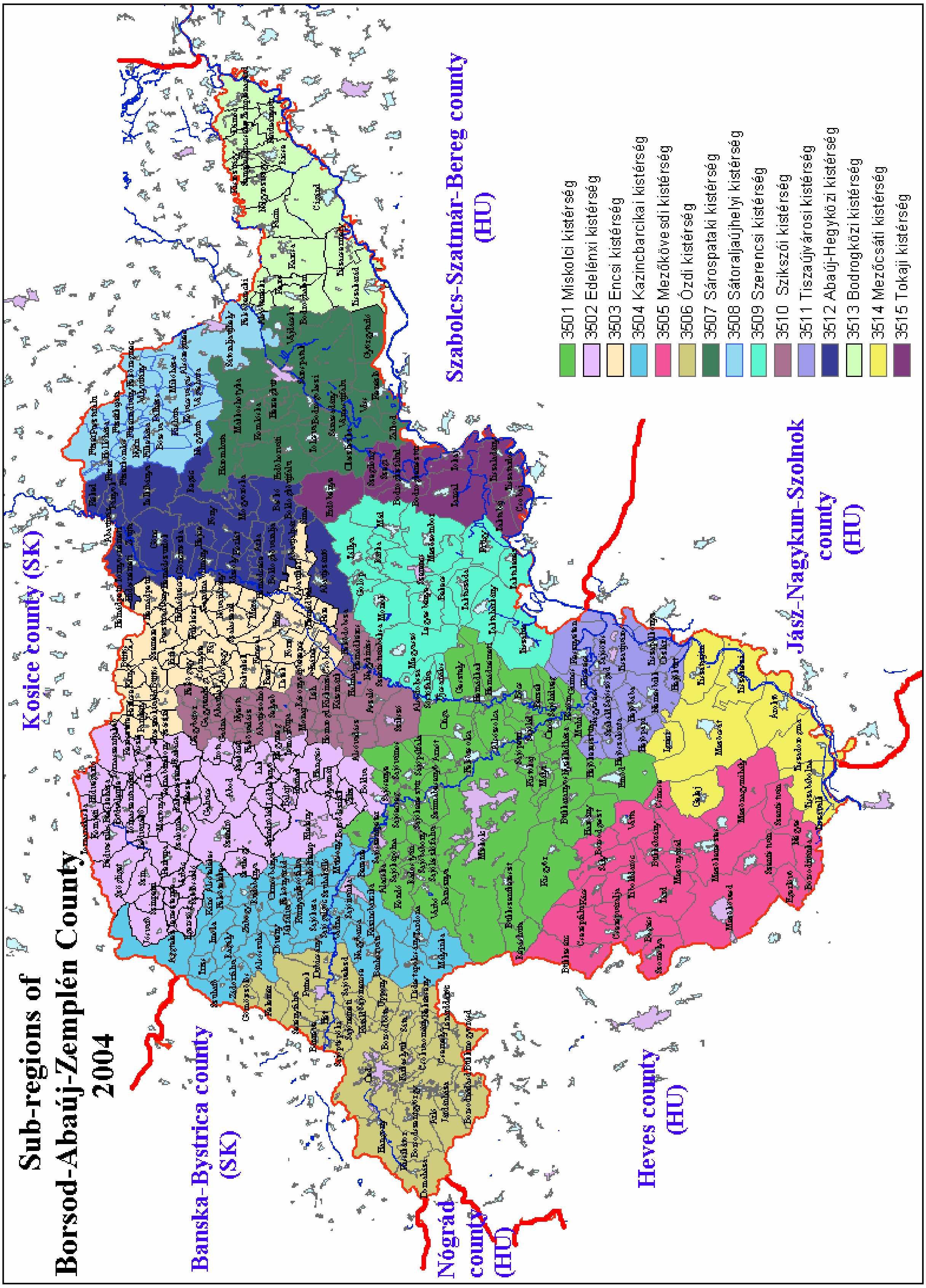


Figure XIII.2: Subregions of BAZ [KSH, 2006]

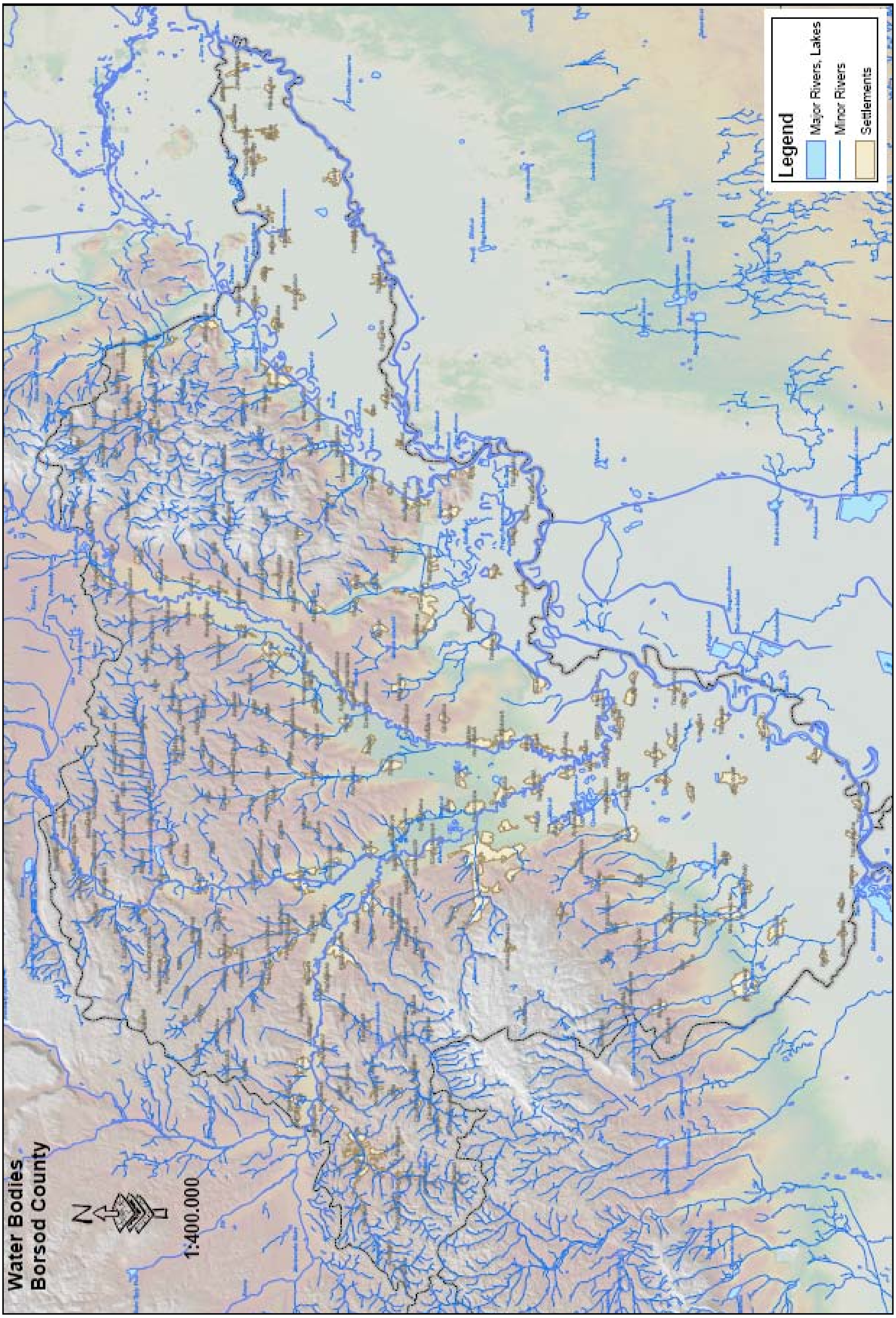


Figure XIII.4: Water bodies in BAZ (compiled by Lajos Dobrosi)

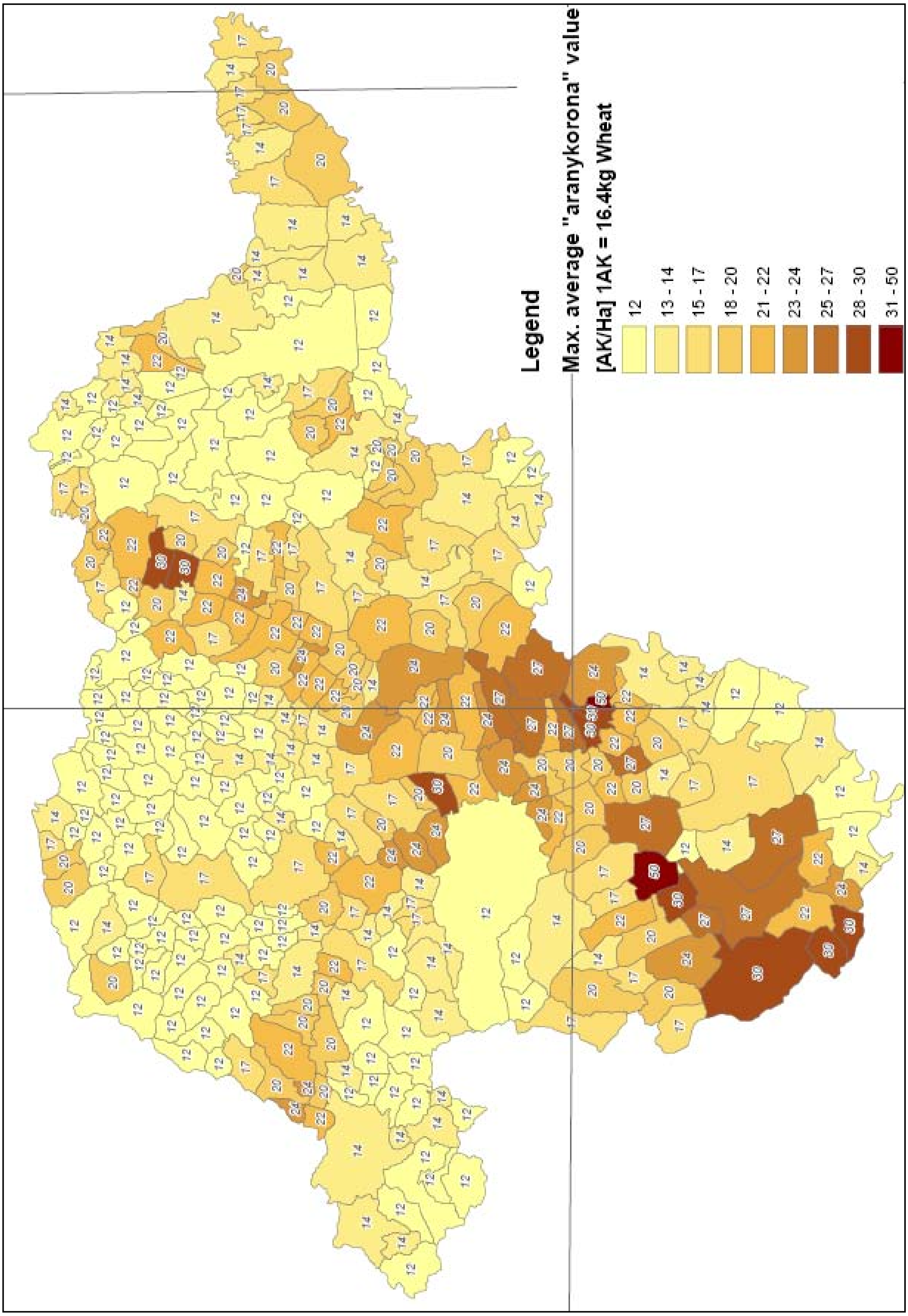


Figure XIII.5: Territorial structure of soil quality expressed in Golden Crown Value (aranykorona) [Dobrosi, 2007]

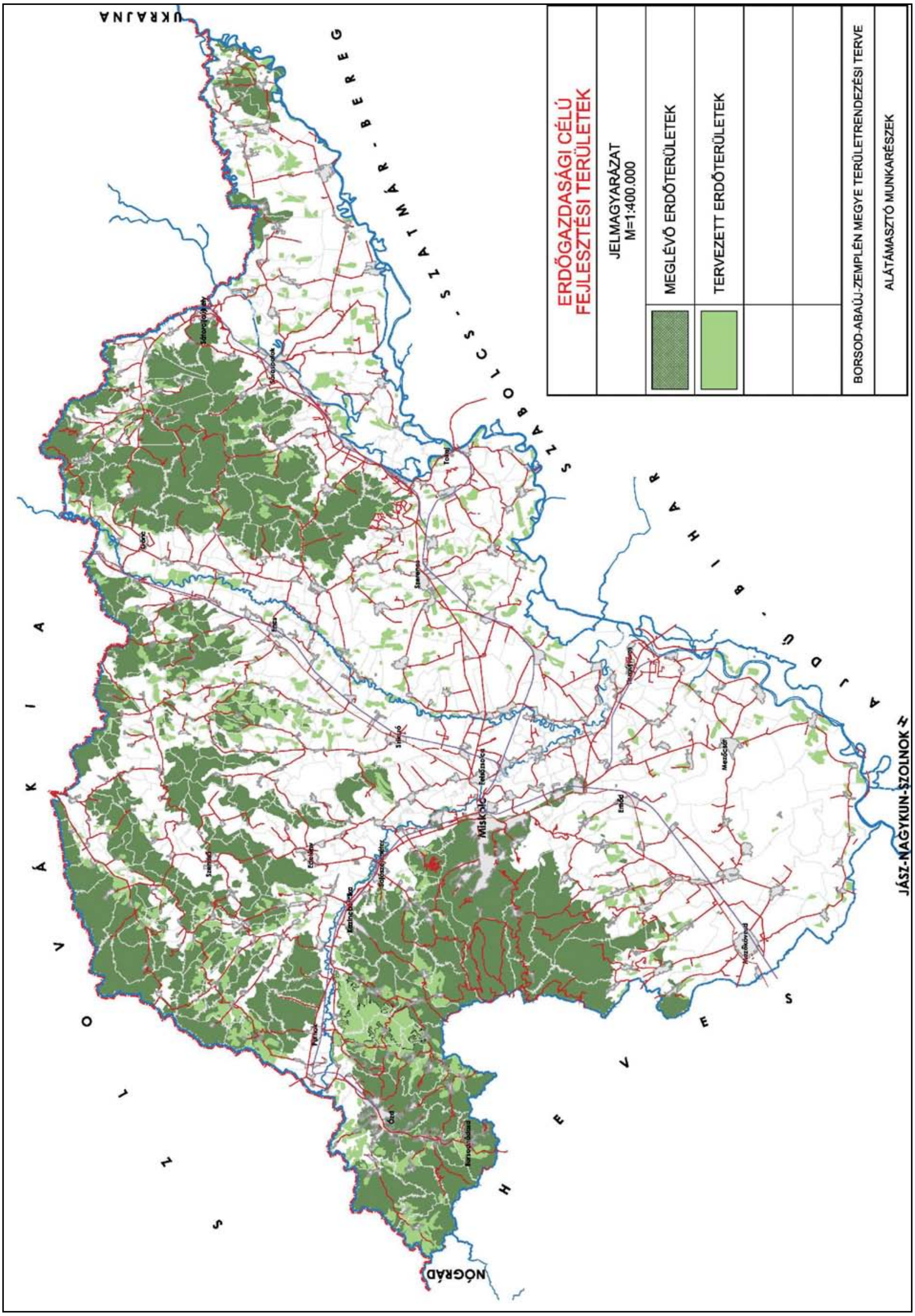


Figure XIII.6: Development areas with forestry purpose *(Comments: Meglévő erdőterületek = existing forest areas, Tervezett erdőterületek = planned forest areas)* [Koszorú, 2002]

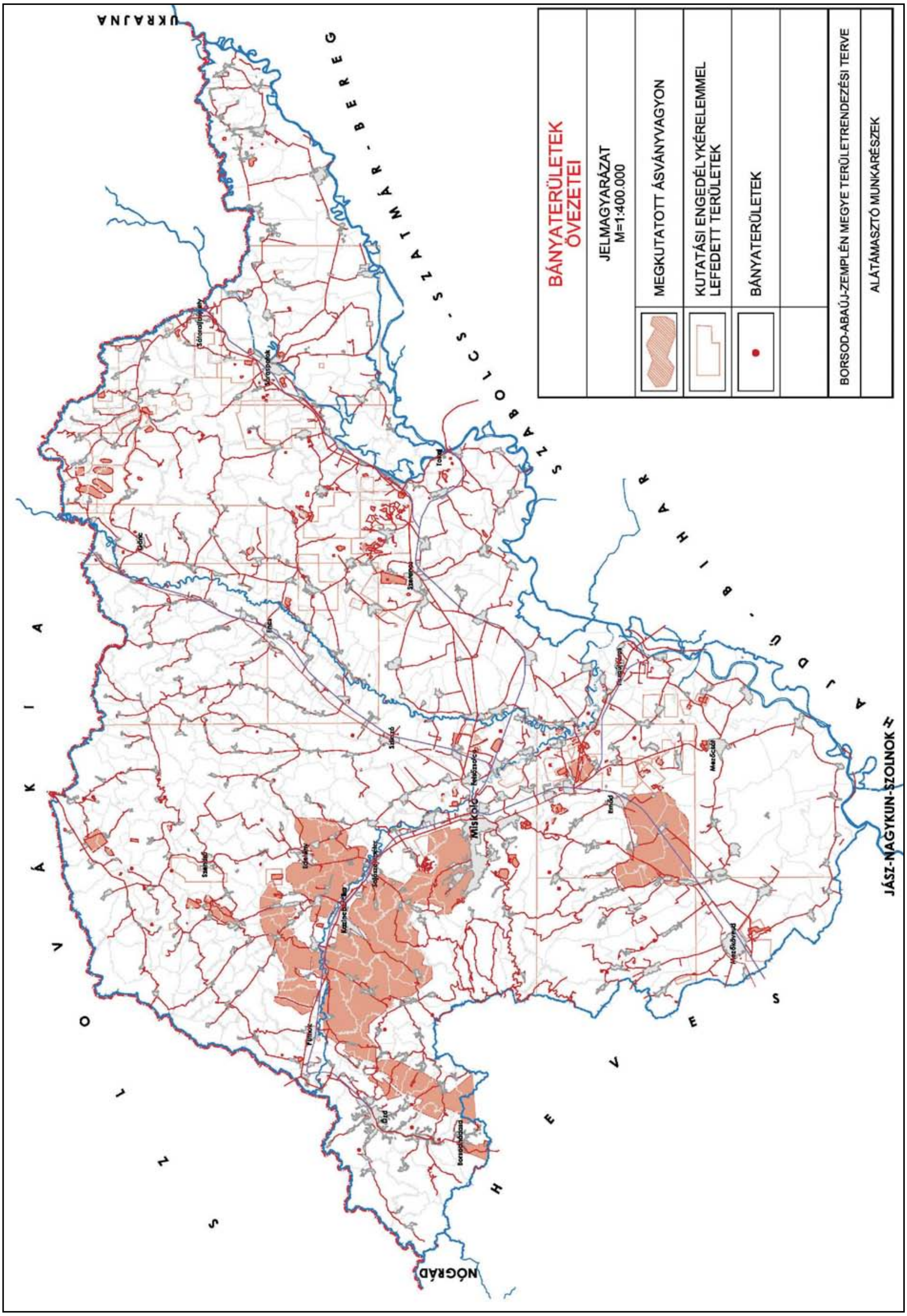


Figure XIII.7: Zones of mining areas in BAZ [Koszorú, 2002]

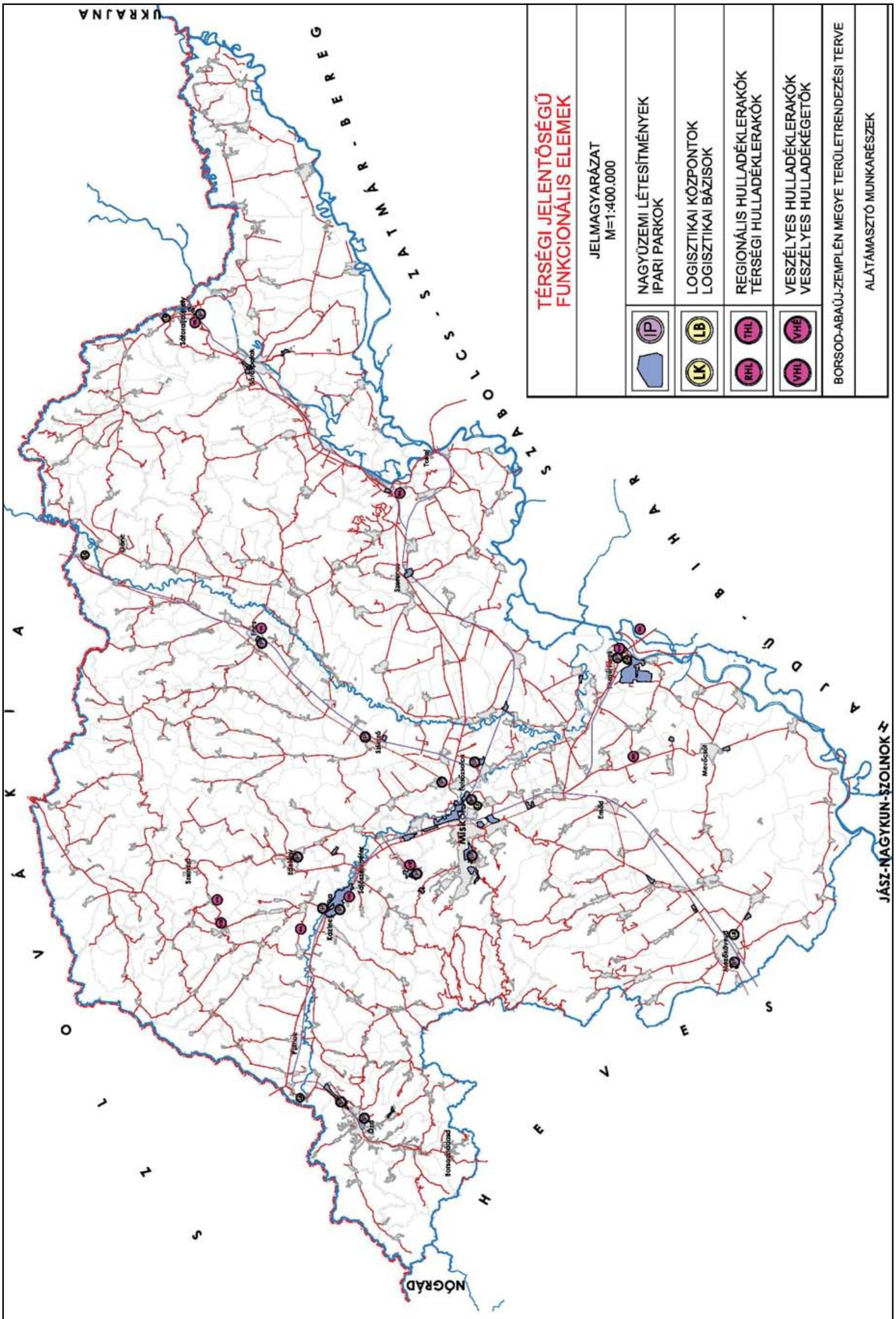


Figure XIII.8: Functional components with regional importance *(Comments: IP = Industrial park; LK, LB = Logistics centre/basis; RHL, THL = Regional waste disposal sites; VHL, VHÉ = Dangerous waste disposal site/incinerator)* [Koszorú, 2002]

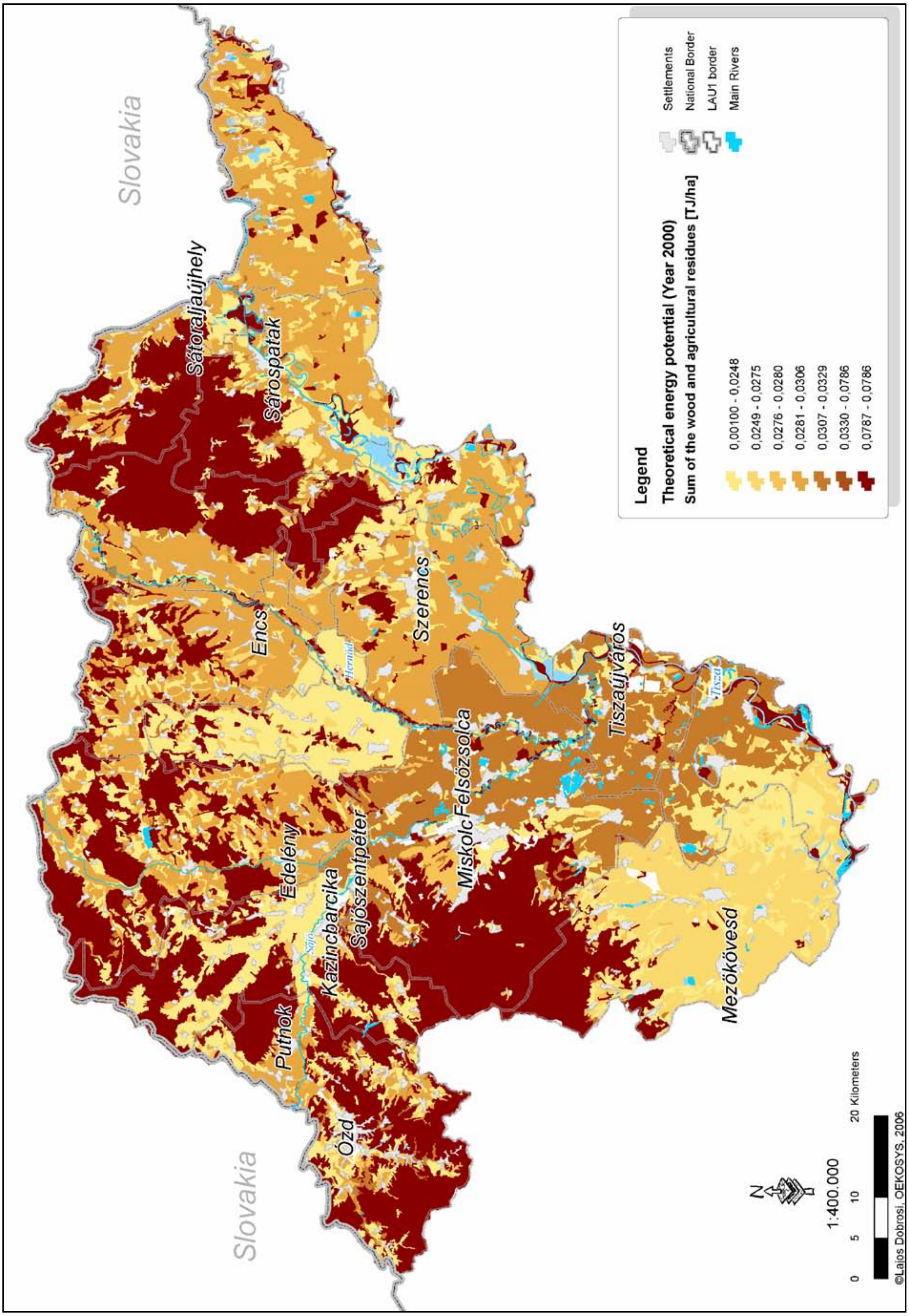


Figure XIII.9: Theoretical energy potential from forest wood and agricultural residues in BAZ in 2000 [Dobrosi, 2007]

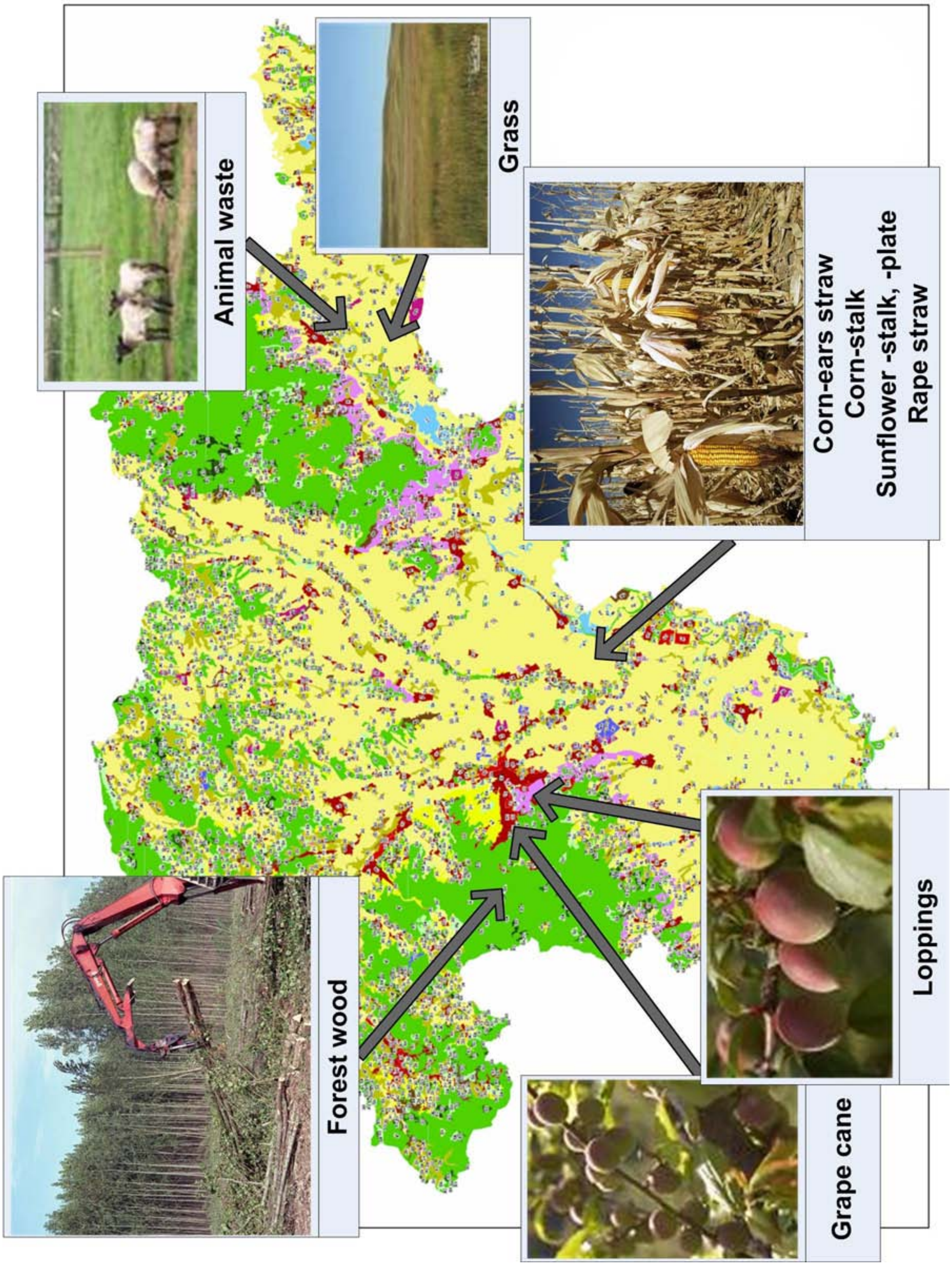


Figure XIII.10: Considered bioenergy resources in the territorial potential analysis in BAZ [Dobrosi, 2007]

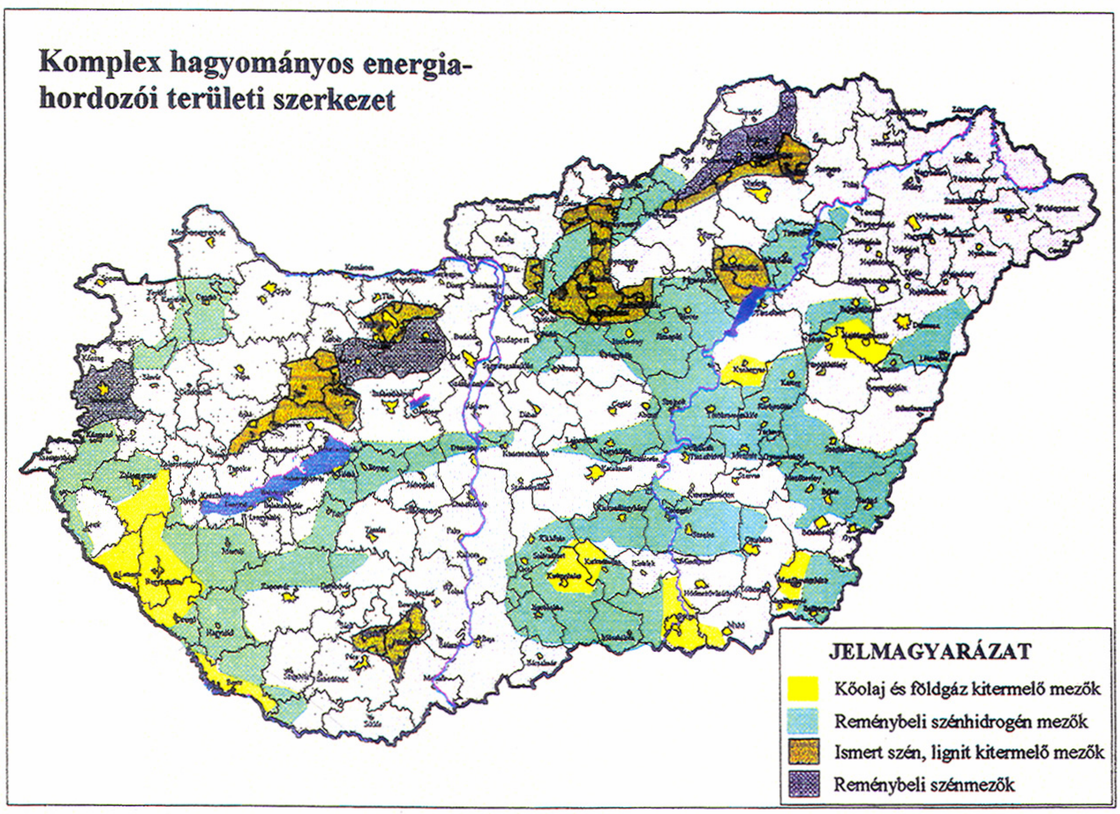


Figure XIII.11: Complex territorial structure of conventional energy carriers in Hungary [Unk, 1996]

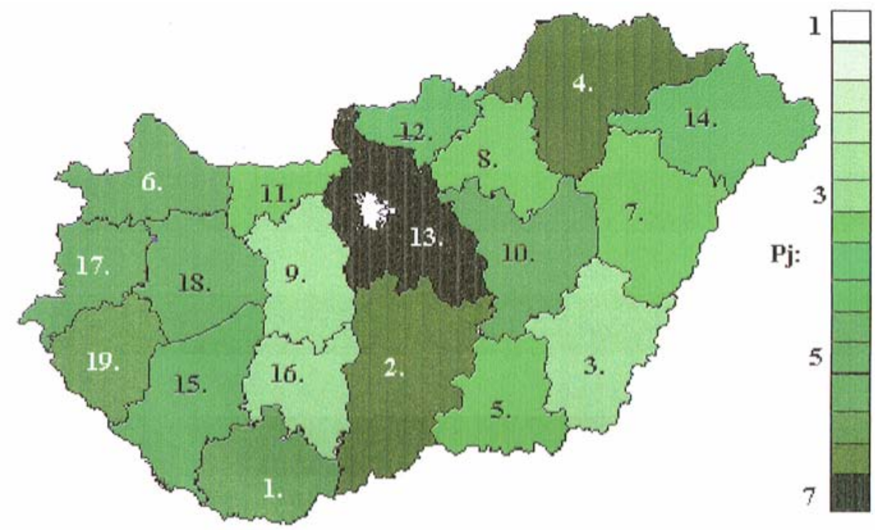


Figure XIII.12: Energy content of total biomass by counties [Unk, 1999]

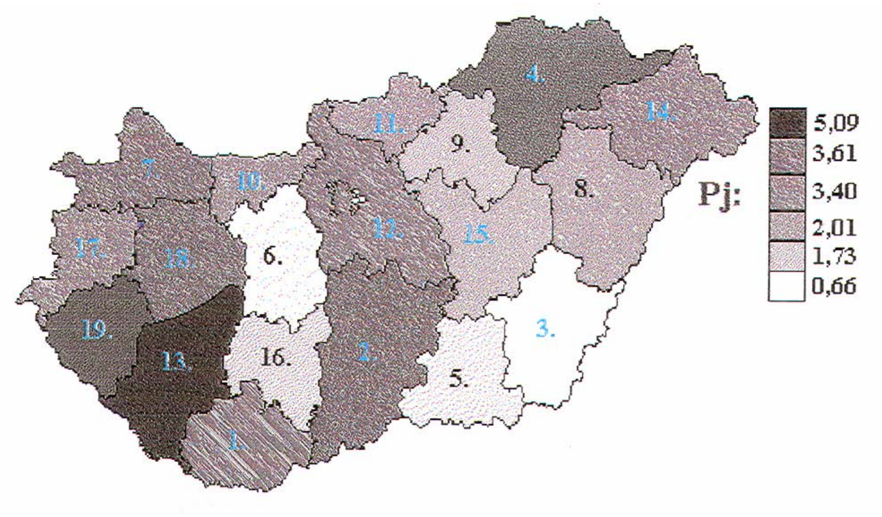


Figure XIII.13: Bioenergetic potential of the forest sector: total and for energy purposes [Unk, 1999]

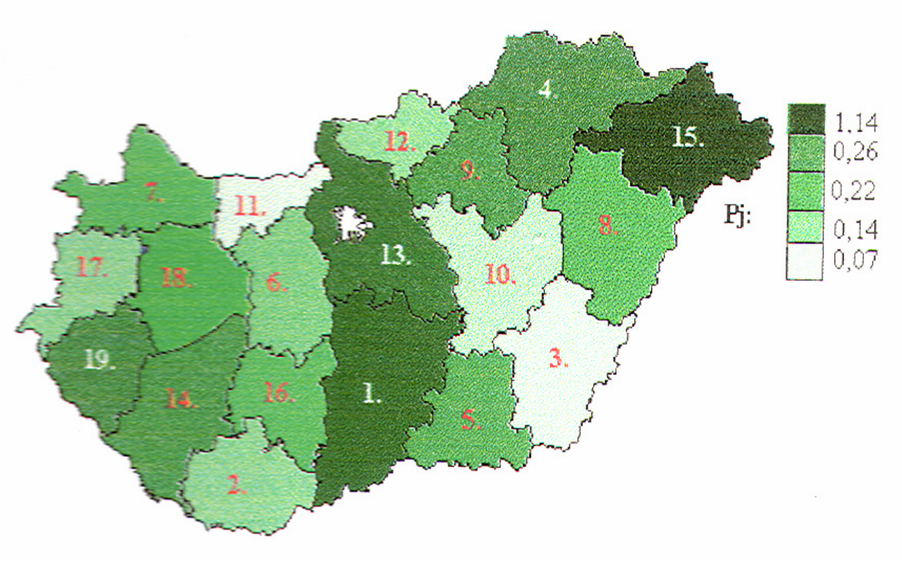


Figure XIII.14: Spatial distribution of woody residues [Unk, 1999]

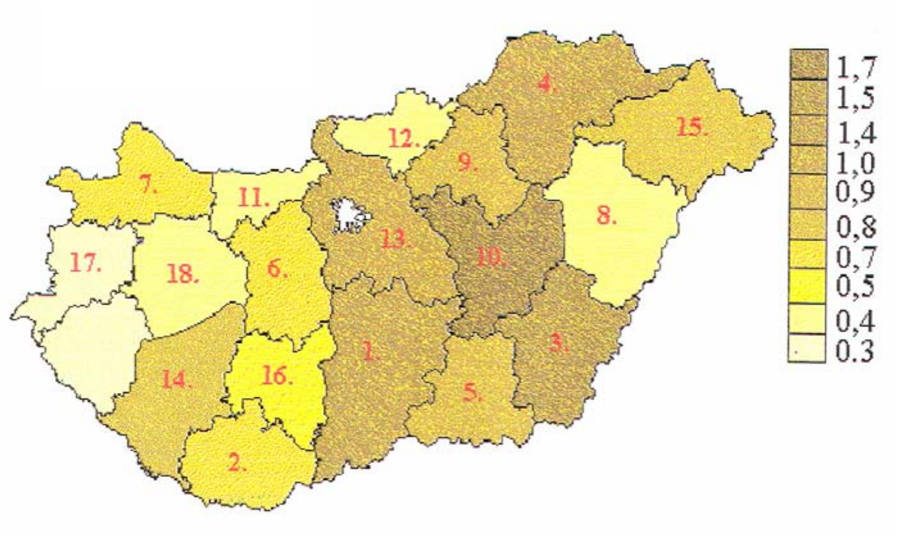
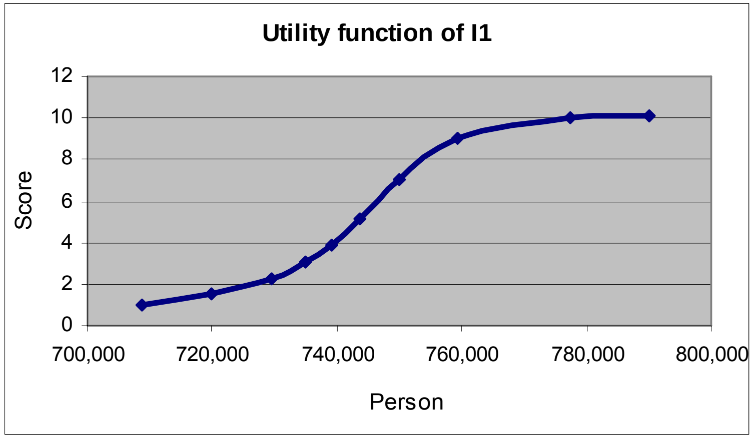
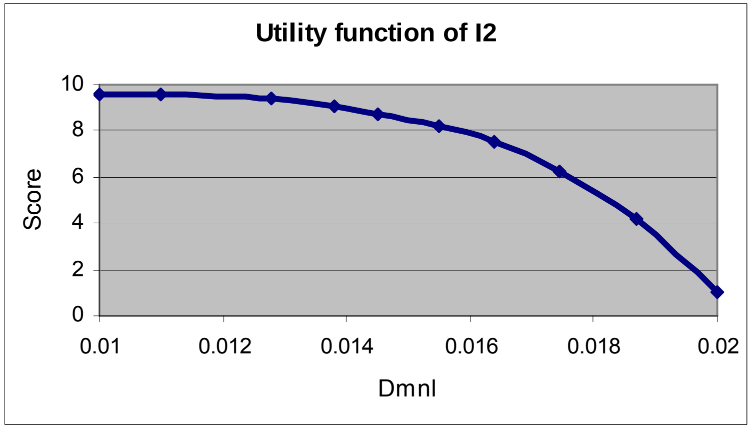
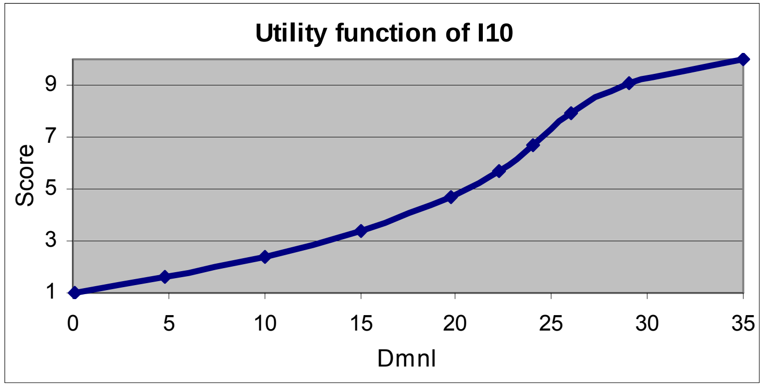
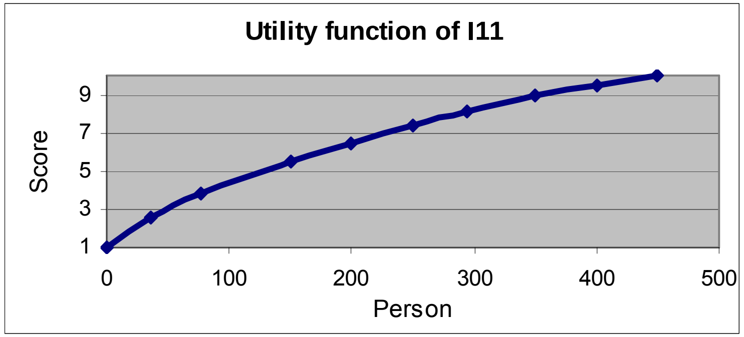
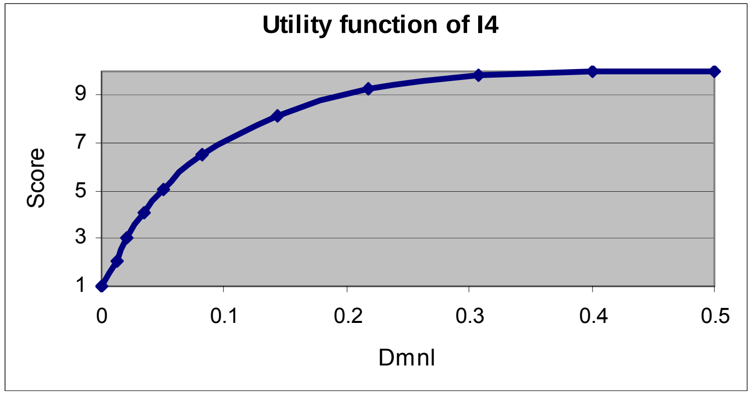
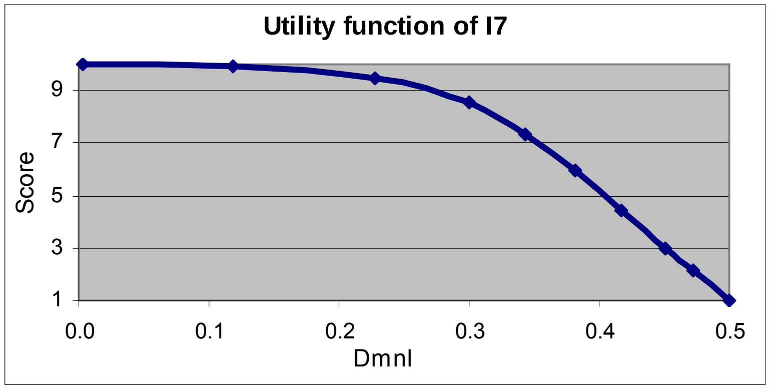


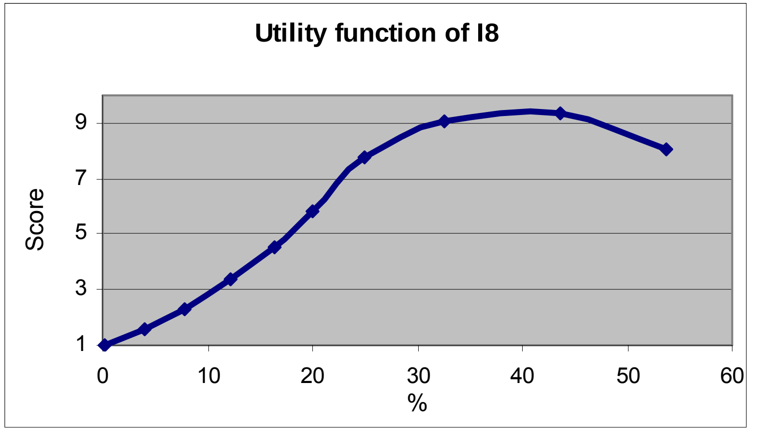
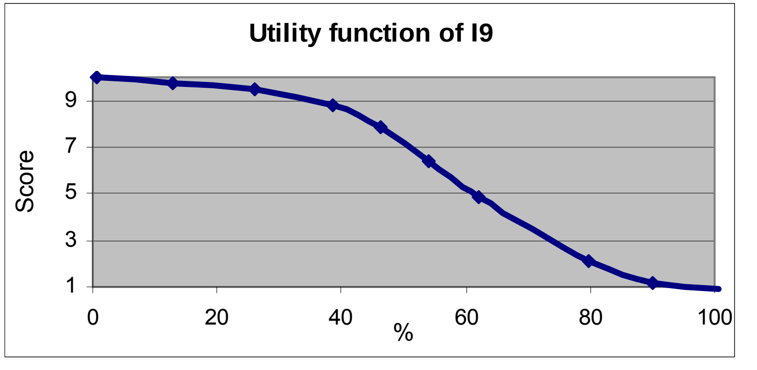
Figure XIII.15: Energy content of usable straw by counties [Unk, 1999]

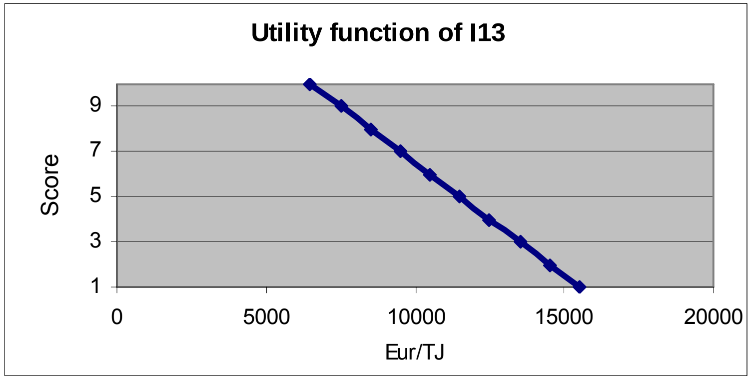
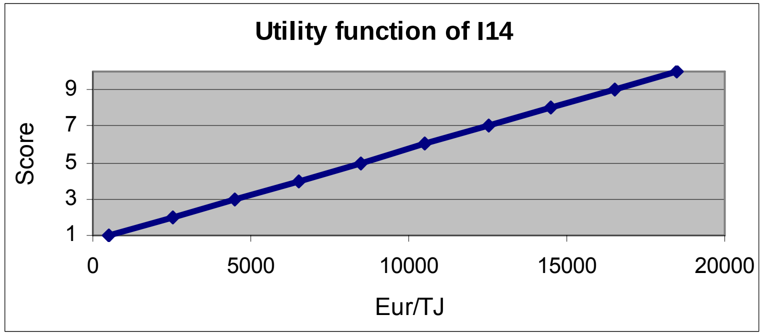
ANNEX XIV. Description of indicators

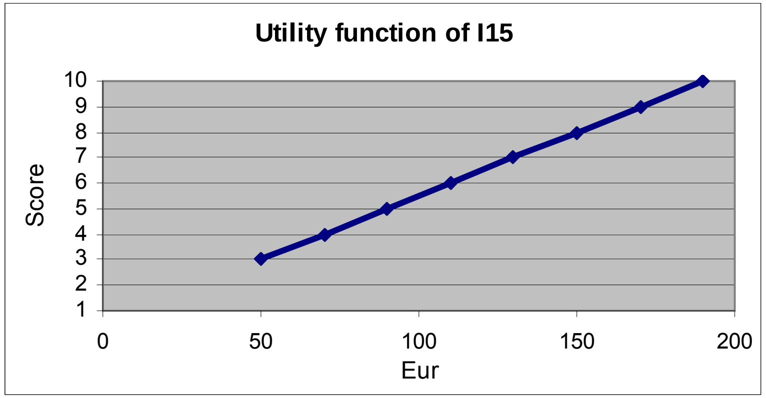
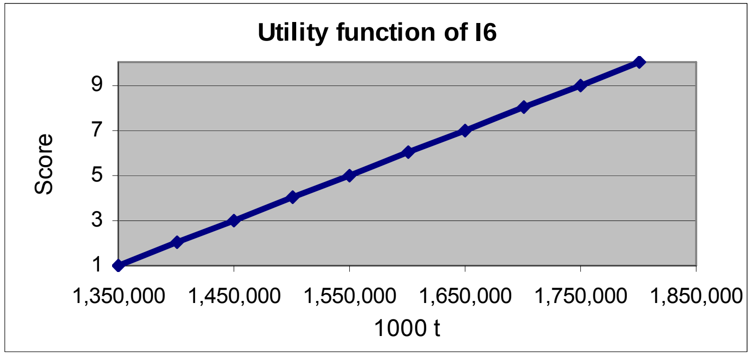
Indicator group	Name	ID	Unit	Description	Utility function
Social Indicators	Number of population	I1	Person	According to the Hungarian Statistics (HCSO), population consists of people living in one area with officially registrated address. People living in an area have several activities, such as working, paying TAX, investigating, buying materials, etc. It would be therefore desired to increase the population up to a desired level, but at least to stop or decrease its decline.	
	Emigration rate	I2	Dmnl	Permanent emigration is the movement of a person leaving its residence and officially signing to another residence (HCSO). Emigration rate is the share of emigrated people to the total population. Unemployement and emigration have a linear correlation (in Borsod) based on historical data analysis. Historically the less emigration took place in 1990 (industrial production), which can be taken as the desired level in the future.	

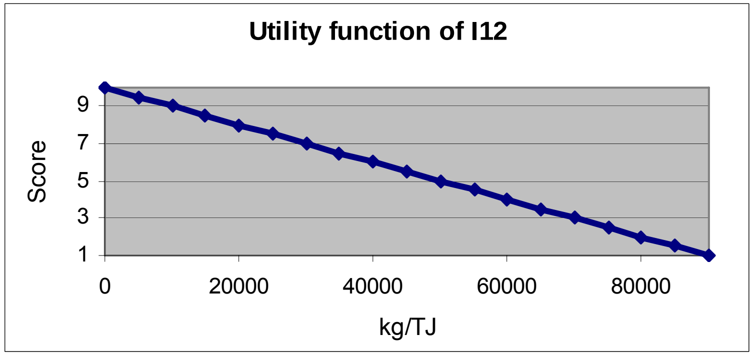
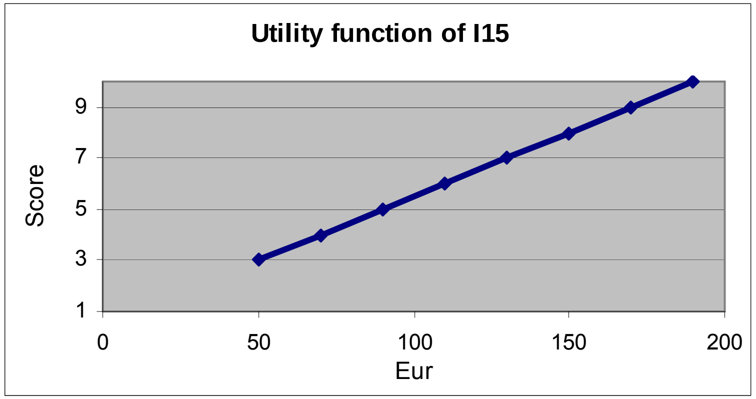
Indicator group	**Name**	**ID**	**Unit**	**Description**	**Utility function**
Social Indicators	Decentralization level of energy supply	I10	Dmnl	The indicator corresponds to the number of plants producing energy in Borsod. It represents therefore the level of decentralization, which's increase is a general objective for any region, to contribute to the security of energy supply.	
	Employment opportunities	I11	Person	Additional employment opportunities generated in the energy sector within Borsod. It contributes to both social and economic enhancement at regional level. Representing new investments in the energy sector generate new jobs for local population.	

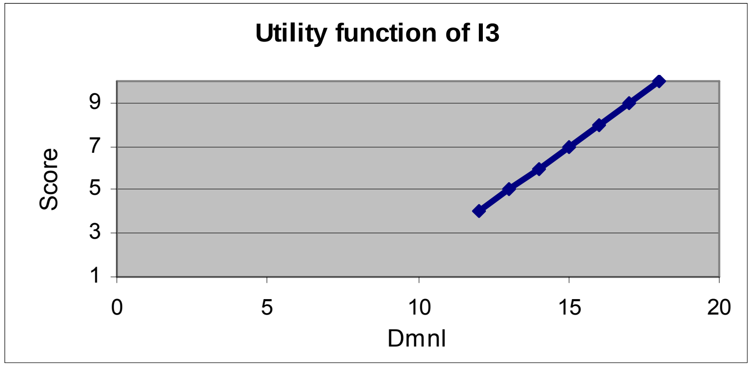
Indicator group	Name	ID	Unit	Description	Utility function
Econo-mic indicators	Unsuitable area utilization rate	I4	Dmnl	The rate resulting from the division of energy plantations and unsuitable arable area. There is a high share (47%) of the arable fields in BAZ with not suitable parameters for traditional crop produtcion. Through establishing plantations for energetic purpose they can be utilized in a more sustainable way, resulting in higher yields and therefore income of marketable new products.	
	Agricultural surplus production	I7	Dmnl	Surplus production of agricultural products. There is a huge surplus production of wheat and maize in Borsod, representing difficulties for their selling, driving therefore low economic performance at rural level. The mitigation of such production is an objective in the overall agricultural sector, which can be partially achieved with a new and competitive production system, involving for example new products.	

Indicator group	Name	ID	Unit	Description	Utility function
Econo-mic indicators	Share of renewable electricity production	I8	%	Share of renewable electricity production in comparison to the total electricity production in BAZ. Generation of electricity based on renewables is European and Hungarian goal and undertaking. There are several support schemes for their economic realization in Hunagry as well. However, for a power security there is an upper limit of renewables, but especially for them depending on the weather.	
	Energy import dependency level	I9	%	Import dependency shows the extent to which a country or region relies upon imports in order to meet its energy needs. It is calculated using the following formula: net imports / gross inland consumption. Within this study the energy resulting form outside of the region was also considered as import. Borsod has a dependency over 70 % resulting from imported (mostly fossil) fuels. The mitigation of this is desired for reasons of economic and environmental enhancement.	

Indicator group	Name	ID	Unit	Description	Utility function
Econo-mic indicators	Unit total cost	I13	EUR/TJ	Cost is the value that must be given up to acquire a good or service. Total cost hier refers to the sum costs related to fuel production, collection, transportation and conversion. Unit total cost shows the costs of one TJ power generation within the region, including the sum of energy generated from all fuel types. It is also included in the gross margin.	
	Unit gross margin	I14	EUR/TJ	Gross margin expresses the relationship between gross profit and sales revenue with the following formula: Revenue-Costs of goods sold. In this study the energy represents the goods sold. Unit gross margin is given for the generation of one TJ power produced within the region. Local and regional aim is to enhance it, even through increase income or decrease costs.	

Indicator group	Name	ID	Unit	Description	Utility function
Econo-mic indicators	Value added	I15	EUR	In macroeconomics value added (VA) refers to the contribution of the factors of production (i.e., land, labor, and capital goods) to raising the value of a product and corresponds to the incomes received by the owners of these factors. VA=Sales-Costs of intermediate goods. VA is overall objective of any regions, especially taking into consideration a low economically developed one, such as Borsod. When applying biomass scenarios, costs of intermediate goods will be minimized, since most of the activities will take place within the County.	
Environ-mental indicators	Oxigen production	I6	1000 t	Generation of oxygen by plants. When planting new woody biomass, there is a significant increase of oxygen production, contributing to environmental and also social enhancement.	

Indicator group	Name	ID	Unit	Description	Utility function
Environ-mental indicators	Unit CO2 emission	I12	kg/TJ	CO2 emission resulting from the generation of one TJ energy. Overall European and Hungarian objective is to decrease its level (Kyoto protocol). The calculated value in this study does not include only the CO_2 emission resulting from the conversion process, but also the those coming from activities related to uel production (e.g. energetic plantations), collection and transport.	
	Energetic plantation index	I5	Dmnl	This index refers to the change of energetic plantation areas in comparison to the total arable area. Since no plantations can be found in the area within the analyzed period (only experimental), its establishment will require a huge effort, srmounting legal and economic barriers. There is however an upper limit of the production extension, when there is no more support or avaiable low quality land, or there is demand for other plants (e.g. food plant).	

Indicator group	**Name**	**ID**	**Unit**	**Description**	**Utility function**
Environ-mental indicators	Diversification level of agricultural products	I3	Dmnl	An index including the number of types of crops produced in Borsod. It is an objective in Hungary, to increase the diversification level of the agricultural products, being available support for that purpose Introducing energetic plantations as new plants icreases this index.	

ANNEX XV: Weights of objectives and indicators

Level 1 priority matrix

		1 Economic prosperity	2 Social equity and cohesion	3 Environmental protection	Weight
1	Economic prosperity	1	3	5	0.648
2	Social equity and cohesion	0.333	1	2	0.230
3	Environmental protection	0.200	0.500	1	0.122

Level 2 priority matrix 1

		1.1. Augment macro level economic growth	1.2. Increase micro level economic development	Weight
1.1.	Augment macro level economic growth	1	4	0.800
1.2.	Increase micro level economic development	0.250	1	0.200

Level 2 priority matrix 2

		2.1. Decrease unemployment	2.2. Better rural social conditions	Weight
2.1.	Decrease unemployment	1	3	0.750
2.2.	Better rural social conditions	0.333	1	0.250

Level 2 priority matrix 3

		3.1. Mitigate emission to the air	3.2. More sustainable land use	3.3. Enhance biodiversity	Weight
3.1.	Mitigate emission to the air	1	4	6	0.701
3.2.	More sustainable land use	0.250	1	2	0.193
3.3.	Enhance biodiversity	0.167	0.500	1	0.106

Level 3 priority matrix 1

		I4 Unsuitable area utilization rate	I7 Agricultural surplus production	I8 Share of renewable electricity production	I9 Import dependency level	I15 Vaue added	I10 Decentralization level of energy supply	I11 Additional manpower employed	Weight
I4	Unsuitable area utilization rate	1	0.25	0.17	0.13	0.14	0.14	0.17	0.023
I7	Agricultural surplus production	4	1	0.33	0.20	0.25	0.25	0.33	0.052
I8	Share of renewable electricity production	6	3	1	0.33	0.50	0.50	1.00	0.115
I9	Import dependency level	8	5	3	1	2.00	2.00	3.00	0.308
I15	Vaue added	7	4	2	0.5	1	1	2	0.193
I10	Decentralization level of energy supply	7	4	2	0.5	1	1	2	0.193
I11	Additional manpower employed	6	3	1	0.333333333	0.5	0.5	1	0.115

Level 3 priority matrix 2

		I13	I14	I15	
		Total cost	Gross margin	Value added	**Weight**
I13	Total cost	1	4	6	**0.701**
I14	Gross margin	0.250	1	2	**0.193**
I15	Value added	0.167	0.500	1	**0.106**

Level 3 priority matrix 3

		I2	I11	
		Emigration rate	Additional manpower employed	**Weight**
I2	Emigration rate	1	0.50	**0.333**
I11	Additional manpower employed	2.000	1	**0.667**

Level 3 priority matrix 4

		I1	I10	
		Number of population	Decentralization level of energy supply	**Weight**
I1	Number of population	1	0.50	**0.333**
I10	Decentralization level of energy supply	2.000	1	**0.667**

Level 3 priority matrix 5

		I6	I12	
		Oxygen production	CO2 emissions	**Weight**
I6	Oxygen production	1	1	**0.500**
I12	CO2 emissions	1.000	1	**0.500**

Level 3 priority matrix 5

		I5	I4	
		Energy plantation index	Unsuitable area utilization rate	**Weight**
I5	Energy plantation index	1	1	**0.333**
I4	Unsuitable area utilization rate	2.000	1	**0.667**

ANNEX XVI: Scenarios of biomass model

Table XVII.1: Data set of the scenarios

Power plant characteristics		Scenario 1 Retrofit biomass power plant	Scenario 2 Straw power plant
Technological parameters	Type of technology	biomass fired steam boilers with stationery fluidized bed and steam turbine	straw fired steam boilers, conventional water-steam cycle, steam turbine
	Life span, a	20-25	20-25
	Space demand, ha		2.6
	Power Capacity, MW	30	50
	Produced power, GWh/a	220	394.5
	Power efficiency, %	28	32.23
	Operation hours, h	7,500	8,000
	Feedstock characteristics		
	Feedstock type	forest wood, energy wood	Hesston straw-bales
	Heating value, MJ/kg	14	13.5
	Moisture content, %	30	18
	Feedstock demand, t/a	200,000	250,000
	Feedstock transport on site	log-gripping machines, high power straddle crane with a wingspan, bridge crane with grab, conveyor for chips	
Manpower demand	Manpower demand, person/TJ produced power	0.14	0.09
Costs	Investment, Mio EUR	8.5	113
	Running costs, EUR/TJ produced power (2004)	10,863	10,863
	CO_2 emissions by operation	0	0
	CO_2 emissions by construction	neglected	neglected

Feedstock production, collection/harvest characteristics		Scenario 1		Scenario 2
		SCR (poplar)	Forest wood	Straw
Technological parameters	Feedstock field demand, ha	10,000		80,000-100,000
	Life span, a	20		
	Cutting cycle, a	4		
	Harvestable yield, t/ha/a (2004)	12.8-17.3		2.5
Manpower demand	Plantation (est+cult+harv) manpower, person/ha	$6*10^{-3}$		
	Collection manpower, person/t			$1.05*10^{-8}$
	Logging manpower, person/t		$5*10^{-4}$	
Costs	Establishment cost, EUR/ha (2006)	1,102		
	Cultivation cost, EUR/ha (2006)	157		
	Harvest cost, EUR/ha (2006)	374		
	Collection cost, EUR/t (2004)			1.7
	Logging cost, EUR/t (2004)		3.529	
Emissions	CO_2 plantation (est+cult+harv), kg/t	7.176		
	CO_2 collection, kg/t			11.151
	CO_2 logging, kg/t		3.89	

Feedstock transport characteristics		Scenario 1		Scenario 2
		SCR (poplar)	Forest wood	Straw
Technological parameters	Transport from field	truck	railway, truck	truck
	Feedstock transport distance, km	30	25 (truck)	50
Manpower demand	Transport manpower, EUR/tkm	$5.7*10^{-7}$	$5.7*10^{-7}$	$5.7*10^{-7}$
Costs	Transport cost, EUR/tkm (2004)	0.043	0.043 (truck)	0.043
Emissions	CO_2 transport, kg/tkm	0.173	0.173	0.173

Figure XVI.1: Woodchips and coal - Borsod power plant [own photo]

Figure XVI.2: Wood processing and the mill house - Borsod power plant [AES, 2004]

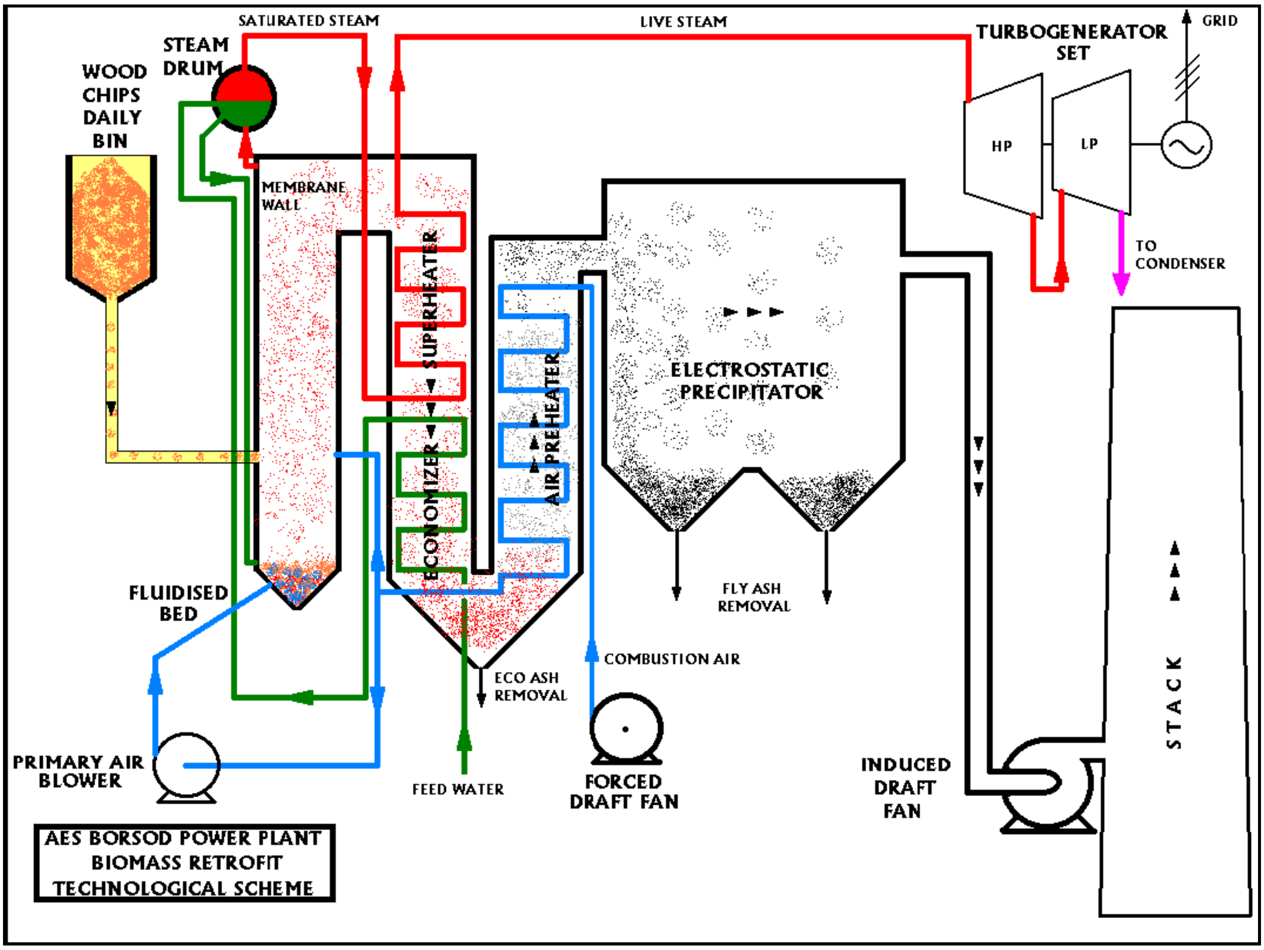


Figure XVI.3: Circuit diagram of the Borsod biomass power plant [AES, 2004]

Figure XVI.4: Baling of straw [NREL, 2006]

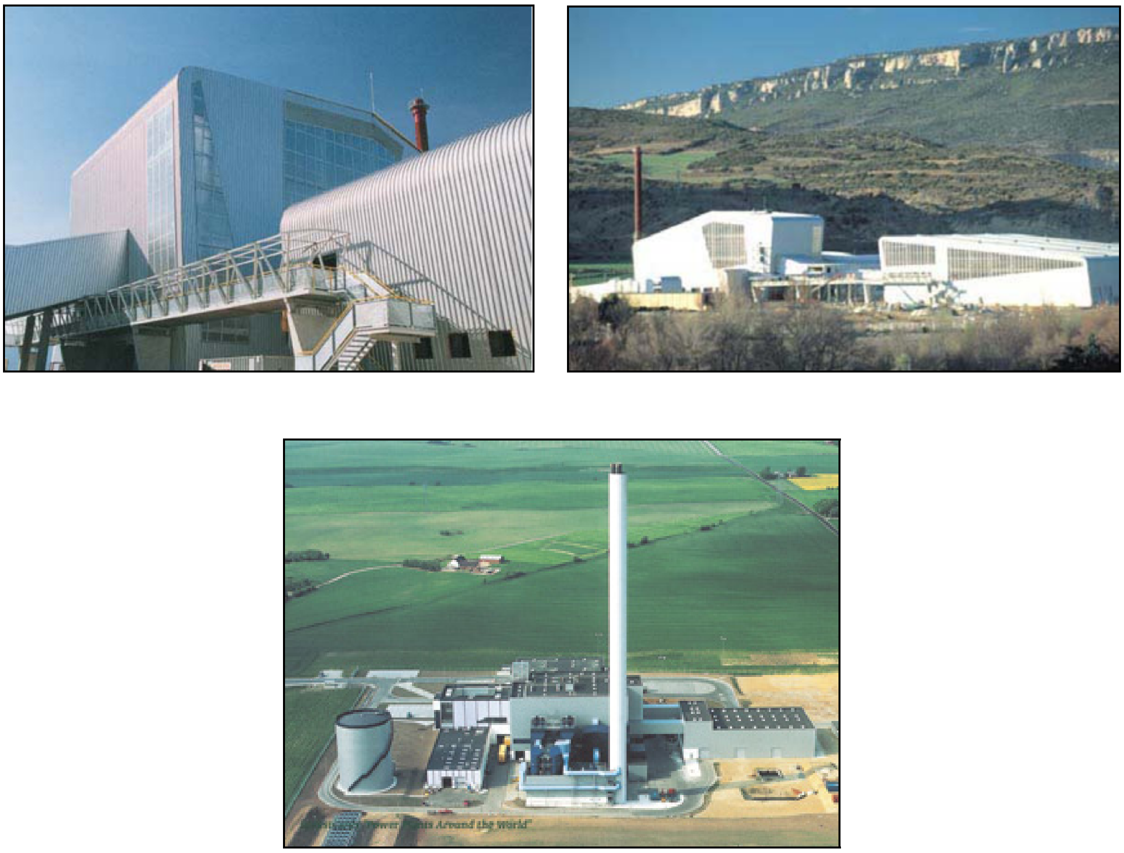
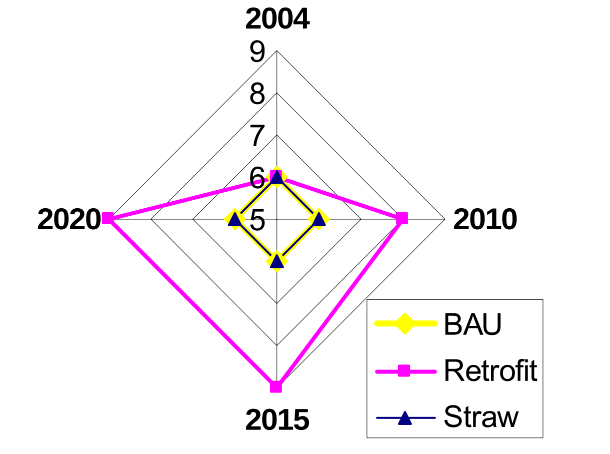


Figure XVI.5: Straw power plant - European reference photos [ETV, 2006]

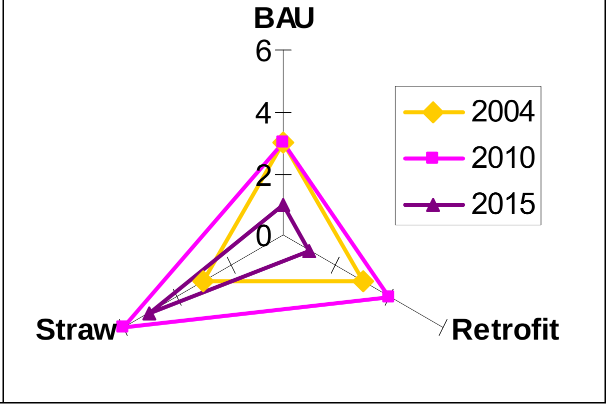
ANNEX XVII: Representation of indicators changes

Scores of selected economic indicators

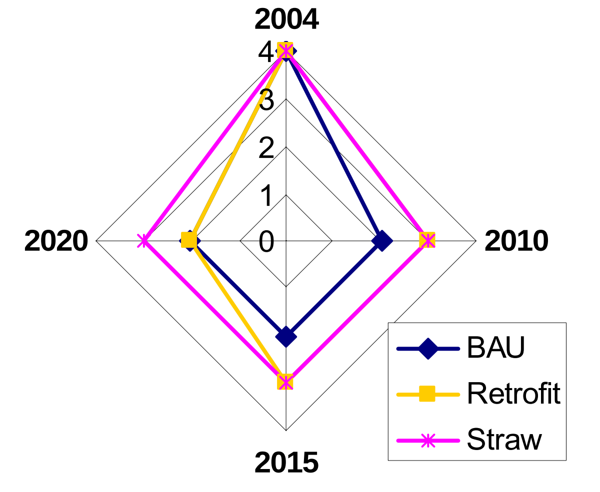
Agricultural surplus production (I7)



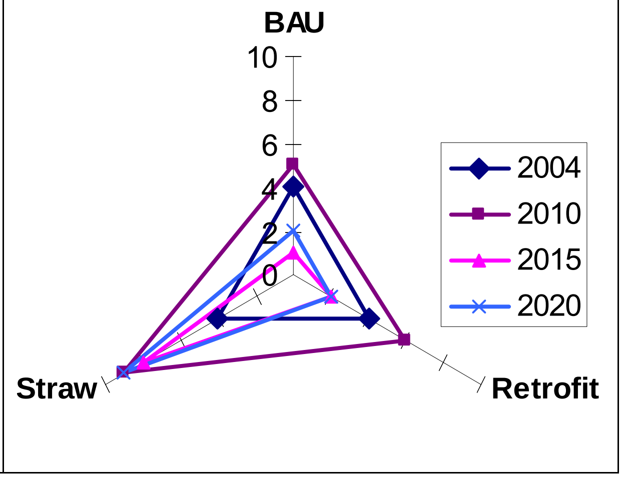
Share of renewable electricity production (I8)



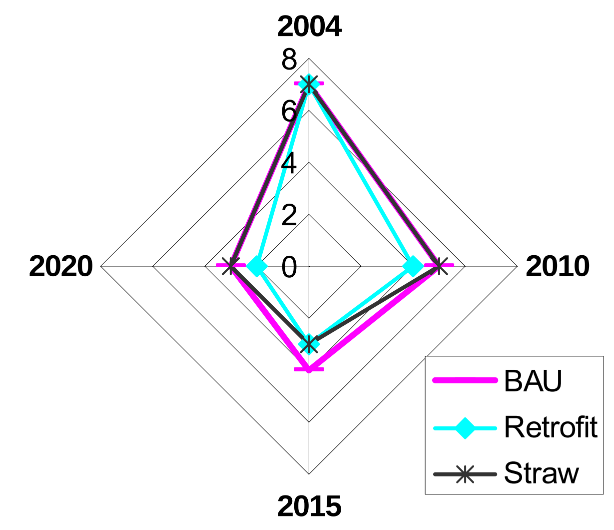
Energy import dependency level (I9)



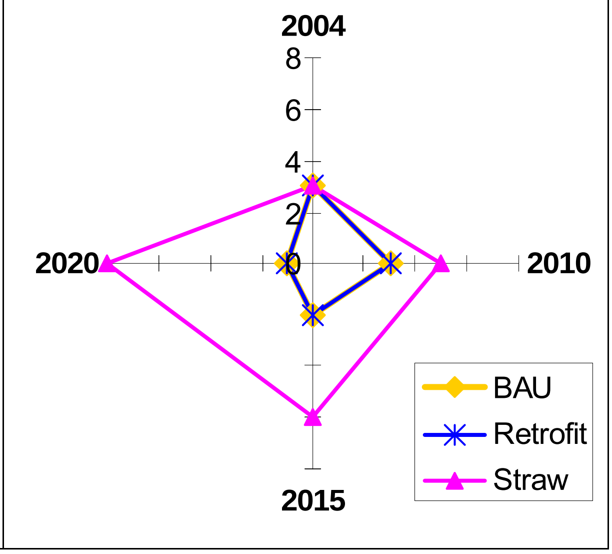
Value added (I15)

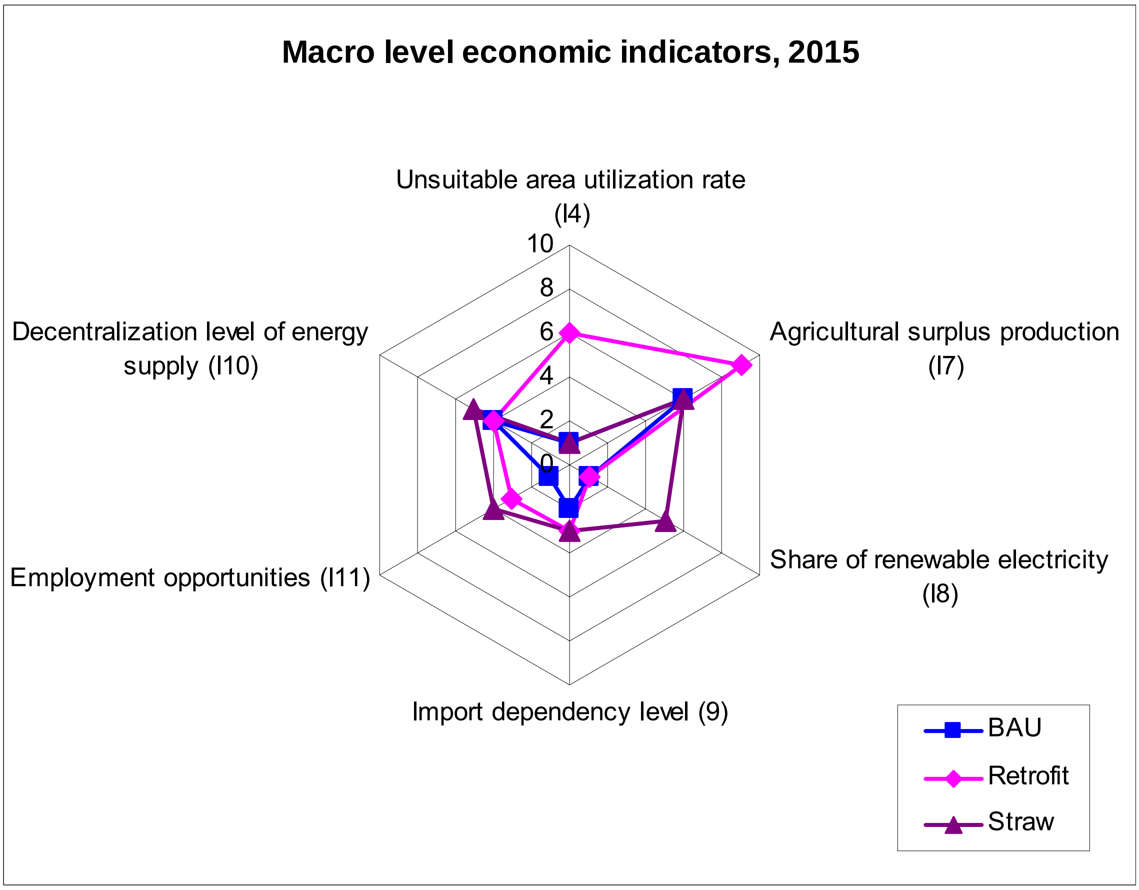


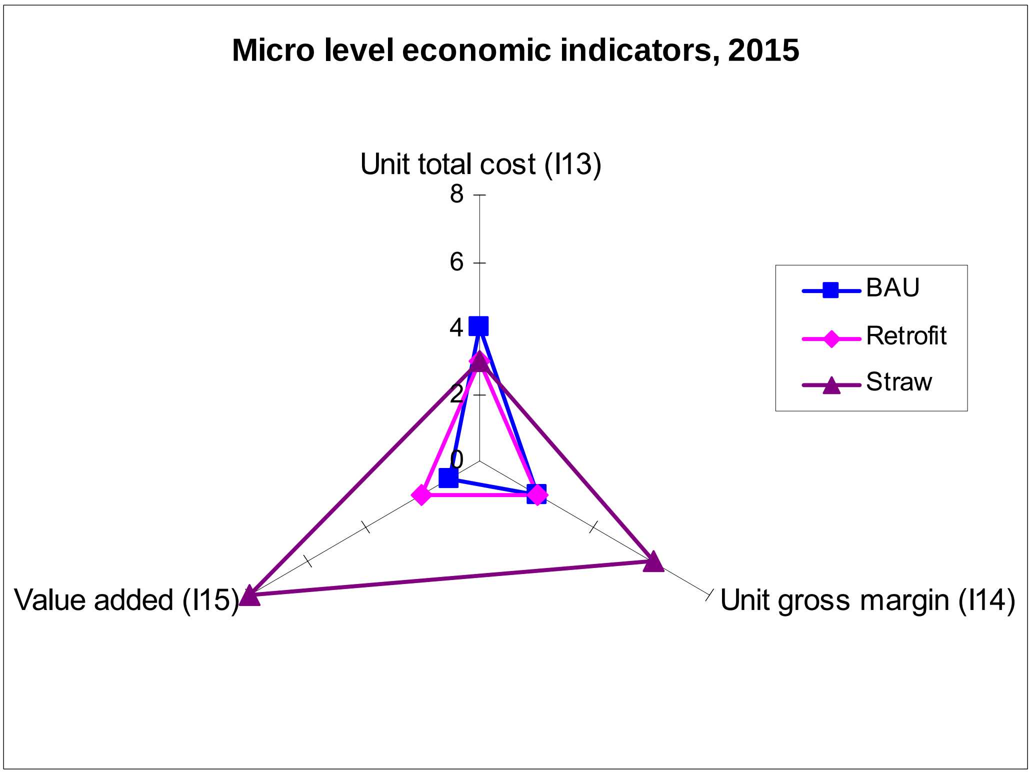
Unit total cost (I13)



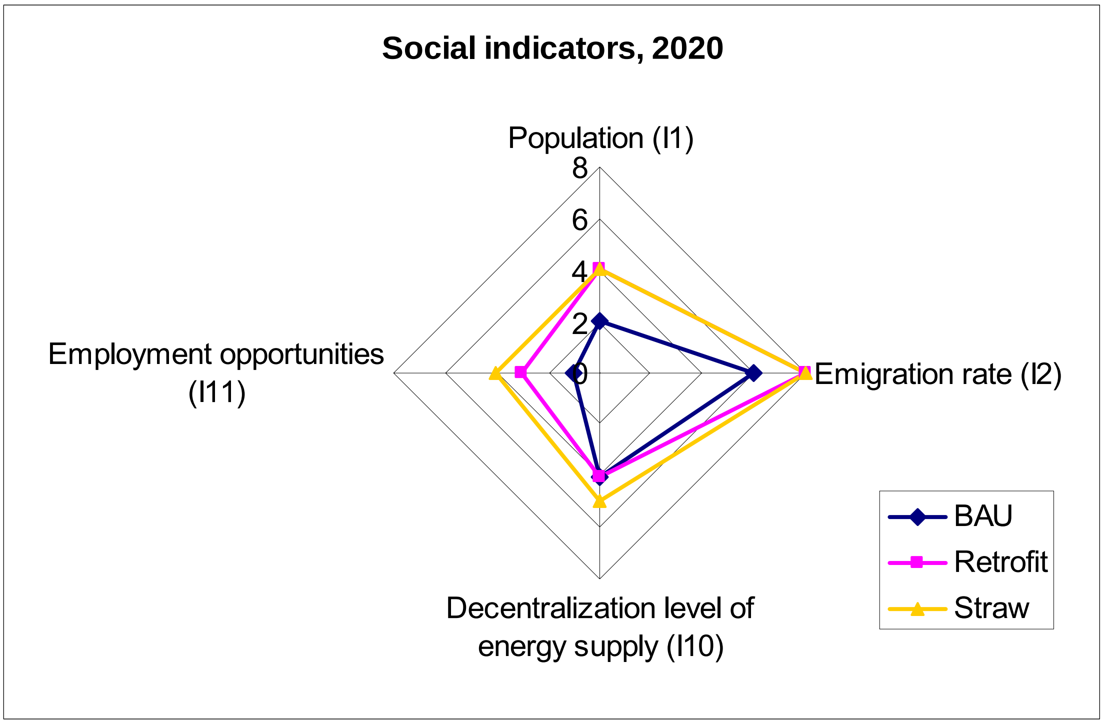
Unit gross margin (I14)

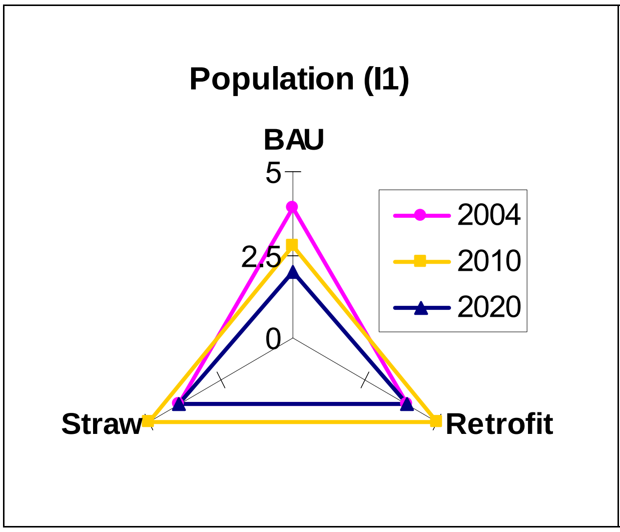


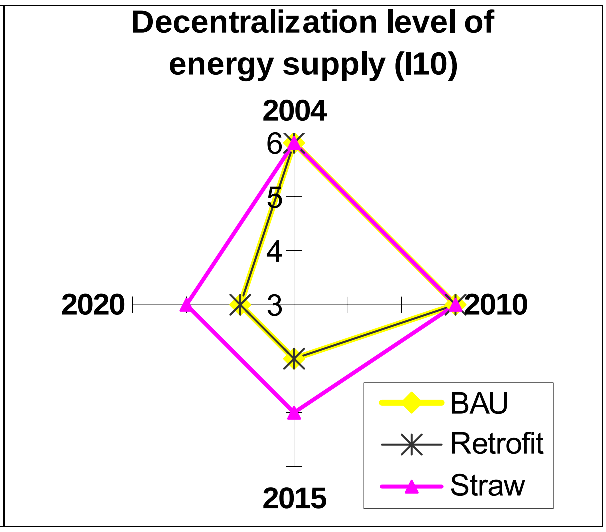

Macro level economic indicators, 2015
Unsuitable area utilization rate (I4)
10
8
6
4
2
0
Agricultural surplus production (I7)
Share of renewable electricity (I8)
Import dependency level (9)
Employment opportunities (I11)
Decentralization level of energy supply (I10)
BAU
Retrofit
Straw


Micro level economic indicators, 2015
Unit total cost (I13)
8
6
4
2
0
Unit gross margin (I14)
Value added (I15)
BAU
Retrofit
Straw

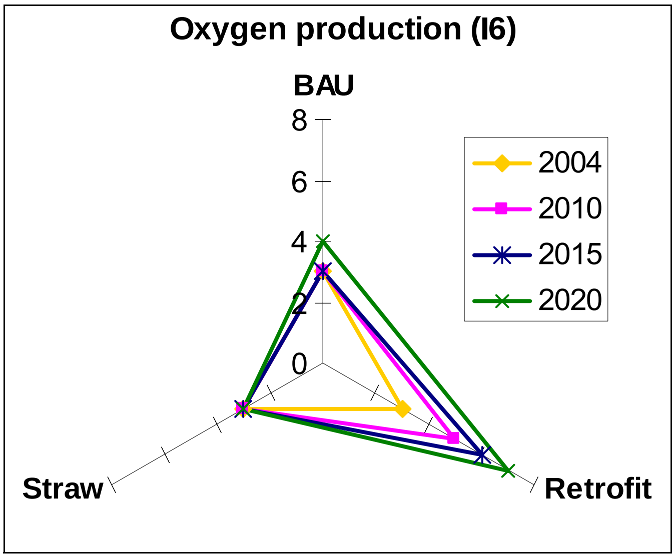
Scores of selected social indicators

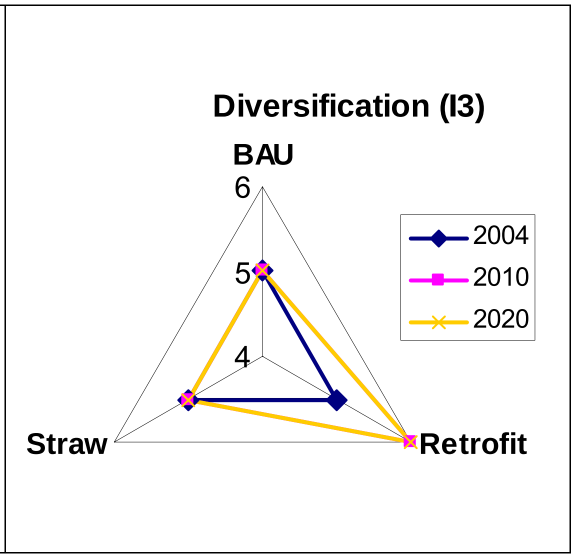


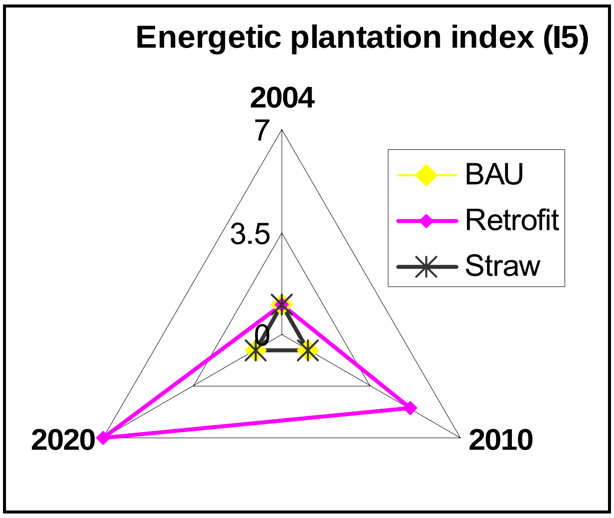




Scores of selected environmental indicators







Scores of selected sustainability level