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Key factors in the potential of biomass for energy purposes

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Abstract

The aim of this thesis is to identify the key factors that affect the biomass potential for energy purposes in the EU-15 in the short term (2010) and in the long term (2050) and to examine the extent to which these factors are taken into consideration in recent European biomass potential studies. In the short term, the production and use of energy carriers based on renewable energy sources (RES) needs to be tested. The identified key factors are: (1) local capacity through the development of pilot projects, and (2) supply chain coordination. In the long term, other key factors for large scale introduction of bioenergy include: (1) land use, (2) efficiency in the yield, conversion technology and end-use, (3) price competitiveness, (4) climate change, (5) policies and (6) integration. These key factors rely on sub-factors due to their complexity. These factors are interrelated; the outcome of one affects the others creating a dynamic system. Giving significance to their interrelation, policies have a higher impact. They influence land use and price competitiveness. Climate change influences the efficiency, and then affects the price competitiveness. Thus, policies are the root cause, which moves the system, while the price competitiveness shows the outcome of the whole system. On the other hand, biomass potential estimations carried out by recent European studies shows a variation between 3.1 to 11.7 EJ y^{-1}. Their methodologies, approaches, potential, source of data and key factors taken into consideration are as diverse as their outcomes. The key factors are used in the estimation of the biomass potential. However, some of these factors are well developed and explained, while others are just mentioned. These identified key factors can help to estimate the potential of biomass for the EU-15 in the short and long term, using different scenarios.

Executive Summary

The increase of demand for oil is projected around 70% by 2030. This great dependence on oil in Europe has motivated the exploration of new alternative sources. Biomass has generated significant expectations. It can supply CO_2 neutral energy and also help to achieve goals on security of energy supply, low health-environmental impacts, rural development and economic competitiveness. The use of bioenergy for electricity, heating, cooling and transport biofuels has stimulated interest to explore biomass potential. Recent European studies have estimated the biomass potential, but their outcomes are varied.

The aim of this thesis is to identify the key factors that affect the biomass potential for energy purposes in the EU-15 in the short term (2010) and in the long term (2050) and to examine to what extent these factors are taken into consideration in the recent European biomass potential studies. Semi-structured interviews were conducted with researchers and a literature review was used in order to determine the key factors and later the analysis of their role in the biomass potential studies.

Key factors are issues of great significance to increase the actual use of bioenergy in the short and long term. The production and use of energy carriers based on renewable energy sources (RES) needs to be tested in the short term. The first factor identified is the *local capacity* through the development of pilot projects, whose outcomes are: what is the right crop, the characteristics of different resources, and their techno-economic and environmental evaluation. The dissemination of results into the decision making group, local authorities, local agriculture and forestry, energy organizations and citizens in general is needed to encourage them to accept and support biomass. These projects must involve a learning process in the use of the technology and in the relation of all actors in the supply chain. *Supply chain coordination* is the second key factor. It has three components: the supply and demand which should be developed at the same time, then acquisition of a suitable technology and finally market growth.

The factors in the long term for a large scale introduction are: *Land uses, efficiency, price competitiveness, climate change, policies, and integration*. Due to the complexity behind each key factor there are sub-factors that give a complete picture. *Land use* is influenced by population growth and consumption patterns of food and fiber. *Efficiency* is influenced by yield and water availability. Other components in the efficiency are the conversion to secondary carriers and the end-use. The *price competitiveness* is influenced by resource competition, market prices and rising oil prices. C*limate change* affects global hydrology and crop physiology, as well as, yield in energy crops and growth in forests. The *policies* should integrate energy, agricultural, environmental, rural, forest and transport sectors. Also, national and local policies, legislation and promotion have to be coherent. Taxes, subsides and other support schemes are the most effective policy instrument in favor of biomass. *Integration* should involve industry in different projects in order to guarantee their participation and future demand.

These factors are interrelated in a system; the outcome of one of them affects the others. If the policies change, it can affect land uses and price competitiveness. As well as, if climate change increases, it can affect the physiology and yield of energy crops, also the pattern of the precipitation and growth of forests. Besides, it can affect the water availability creating long periods of drought or flooding. Then, climate change affects the efficiency of yield and it affects price competitiveness. Furthermore, the factor with more influence is policies. Its outcome influences directly more factors and it receives the feedback from others, e.g. if climate change is increasing rapidly, it is likely to stimulate new policies. Also if the efficiency increases, economic mechanisms that support biomass could be reduced. On the other hand,

the factor which shows the outcome of the system is price competitiveness. If the efficiency increases due to the learning process or by influence of climate change, then, the price can change. At the same time, the policies affect the price competitiveness. Integration refers to participation by industry and other stakeholders.

In the most recent European studies, the biomass potential varies between 3.1 to 6.2 EJ y^{-1} in 2010, around 4.8 to 7.1 EJy^{-1} in 2020 and between 9.1 to 11.7 EJy-1 in 2050. The most important factor affecting the result is the time frame, which in turn influences land availability for energy crops and yield. More time, more land and more yield results in more potential. Another factor is the resources taken into consideration. The most important resources for biomass potential in the short term are forest residues and industrial and agricultural residues and waste. However, in the long term the contribution of energy crops is much higher.

The authors use different methodologies, different approaches, sources of data, potentials and take into account different key factors. The approaches used are resource-focusing, demand-focusing or both. The sources of data are: surveys, statistics, projections and assumptions. Some of them use the economic and ecological perspectives. The majority use the theoretical and geographical potential. Also, the technical potential is missed in many of them. The economic potential is taken into consideration, but it is often not clear what sub-factors were analyzed in estimations. The implementation potential is considered in some studies, but only some policies and legislation are taken into account.

Regarding to what extent the key factors are considered, the analyzed studies in general do not take into account the key factors in the short term or they are mixed with the long term key factors. In the studies of Nikolaou et al. (2003), Siemons et al (2004), and Karjalainen et al. (2004) where the time perspective is short, from 2000 to 2020, agricultural land for energy crops, yield and forest residues are expected to rise 1% per year or keep stable. However, in Ericsson and Nilsson (2004), which has the longest time perspective, the arable land for energy crop increases from 10% to 25% and in the last scenario agricultural land is above what is assumed to be required for food production (0.24 ha/cap). Also, yield increases 1% per year.

Regarding forests two scenarios are estimated. They are related with high or low harvest ratio in the economic and ecologic perspective. The factors more often discussed are the policies and price competitiveness, but the studies show different sub-factors and do not consider all of them. For Siemons et al. (2004), Karjalainen et al. (2004), and Alakangas et al. (2003) the role of environmental protection in the market through tax exemptions is important, because of their influence on the price. Also, the integration between different policies is important to achieve biomass/biofuel goals. For Nikolaou et al. (2003) the efficiency in yield and conversion technology influences the cost. In general, some factors have interrelations with others, but not all studies show the same interrelations or the same factors. Only one study presents scenarios and suggests the influence of climate change.

These identified key factors can help to estimate the potential of biomass for the EU-15 in the short and long term; using different scenarios. Furthermore, in order to achieve the target in renewable energy sources and the target for the transport sector a change in the current policies is needed.

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1 Introduction

1.1 Context

EU countries share the same four general energy policy goals: secure energy supplies, low health-environmental impacts, rural development and economic competitiveness through higher efficient use and lower cost supply. The security of energy supply implies the continuous availability of energy in sufficient quantity at favorable prices (European Commission, 2002). The International Energy Agency, IEA, in the World Energy Outlook series indicates global primary energy demand is set to increase by 1.7% per year from 2000 to 2030. The increase will be equal to two-thirds of current demand. The uses of fossil fuels emit pollutants, especially CO_2, which contributes to climate change. The CO_2 emission generated in Europe is 94%. It can be attributed to the energy sector in general and in particular to fossil fuels like oil, coal and natural gas (European Commission, 2001). Moreover, emissions of CO_2 will grow a little more quickly than primary energy supply. They are projected to increase by 1.8 % per year from 2000 to 2030 reaching 38 billion tonnes in 2030 according to IEA.

Biomass is important for reducing CO_2 emissions and ensuring the security of energy supply, as well as, to achieve other goals. The use of bioenergy for electricity, heating, cooling and transport fuel has stimulated interest to explore biomass potential. The European Union has set ambitious targets to increase the share of renewable energy sources (RES) in the total energy consumption. By 2010, renewable energy sources shall contribute 12% of gross inland energy consumption (White Paper COM(97) 599). Besides, the biomass-based electricity is promoted through the Green Electricity Directive, aiming to increase its share from 14% to 22% (Directive 2001/77/EC on renewable electricity). The target for the transport sector is 5.75% of biofuels (Directive 2003/30/EC on transport fuels). The European Renewable Energy Council, EREC, and its members, are concerned with the delay of the discussion of new targets for 2020. These targets are inherently linked to the 2010 targets, in the way that setting 2020 targets will accelerate the process of reaching the 2010 targets (EREC, 2005)

It is important to increase the actual use of bioenergy and large-scale production plants. However, it must overcome some barriers such as: difficulties with financing aspects, insufficient acceptance, lack of knowledge by the policy-makers and lack of integration, etc. On the other hand, there are some RES policies and promotion programs to support biomass such as: energy taxation, investment subsidies, support for electricity production from RES, green certificates, deregulation of the electricity market, etc. As a result of this panorama, many actions and studies pertaining to the role of biomass in each EU country have been produced in order to estimate the biomass potential and achieve the different goals. However, these studies identify different biomass potentials because the authors have taken completely different factors into account.

To better understand, it is necessary to identify the key factors that influence the potential of biomass for energy purposes. Besides, this helps to overcome the barriers and to guarantee development of the potential biomass, and at the same time, receive all the benefits of their deployment. Moreover, to understand the interrelation between the different factors helps to recognize their significance in the biomass potential.

1.2 Problem

There is much discussion in the literature regarding the global and European potential availability of biomass in future energy supply. Studies on this issue have arrived at a wide range of conclusions. They have used different methodologies, potentials, approaches, time perspectives, and assumptions. At the same time, they consider different sources and energy purposes. The biomass potential in the short term and long term is varied, as well as, the key factors that influence it.

1.3 Objective and Research Questions

The objectives of this thesis are to identify the key factors that affect the biomass potential for energy purposes in EU-15 in the short term, (2010) and in the long term, (2050) and, to examine what extent these factors are taken into consideration in recent biomass potential European studies.

The recognition of the key factors was done through interviews with different researchers of biomass studies. Knowing that previous studies had identified key factors in biomass markets; the starting point was to recognize if these are still the most important factors in the biomass potential. After their identification, due to the complexity, they were classified as factors and sub-factors. Moreover, they were recognized as factors in the short term or in the long term. Also, the focus is on energy crops and forest residues, because they represent the largest resources for biomass potential in the long term.

The most recent European studies about biomass potential were analyzed, in order to examine what extent the key factors are considered in the short and long term. These studies are: Alakangas and Vesterinen (2003), Ericsson and Nilsson (2004), Nikolaou et al. (2003), Siemons et al. (2004) and Karjalainen et al. (2004). The analysis was done in the short and long term, focusing on the interrelation of the different factors and the determination of their significance. The research questions are therefore: *What are the key factors that affect the biomass potential for energy purposes in the EU-15, in the short and long term? And, how are these key factors taken into account in recent EU studies?*

1.4 Scope and Limitations

The scope is defined by the selected geographical boundaries, studies and biomass resources. *Geographical boundaries*: the research is focused on EU-15 countries. *Studies:* the assessment is done for the following studies: Alakangas and Vesterinen (2003), Ericsson and Nilsson (2004), Nikolaou et al. (2003), Siemons et al. (2004), and Karjalainen et al. (2004). These studies are the most recent studies carried out on the biomass potential in Europe. *Biomass resources:* The analysis is focused only on energy crops and forest residues. These are considered to offer the largest potential growth in the long term. Other sources are not considered such as agricultural residues, waste and industrial residues despite their moderate contribution in the short term.

During this research, it was found that the term biomass is not well defined at EU level. At the same time, the authors, who have estimated the biomass potential in EU, have made different classifications of biomass resources. This means that their outcomes are difficult to compare. Moreover, when these studies mention the potential of energy crops they do not specify any type of energy crops, for that reason their yield is neither specified or sometimes they give an average number.

1.5 Methodology

This research is an exploratory study that follows a *qualitative approach*. This approach is appropriate because identifying the key factors for biomass potential requires information for diverse sectors like energy, agriculture, forestry, environment, rural development, and transport. It needs the contribution of experts, researchers and entrepreneurs. For that reason, *interview* was the main method used in this research. Applying a *literature review*, this information was complemented by secondary sources through research papers, textbooks, and analytical articles; as well as, current relevant legislation. Furthermore, an *analytical framework* was applied to biomass studies, which had estimated the potential of biomass, in order to know what extent these have taken into consideration the key factors identified.

1.5.1 Research Design and Approach

To achieve the research purposes, the first step involved reviewing two studies which identify the critical factors to bioenergy implementation and identify the socio-economic and institutional barriers. These studies were written by Roos et al. (1999) and Hezik and Madlener (2003). In order to know, if these factors and barriers are still valid, the questions in the interviews were based on the result presented in those studies. This questionnaire is shown in Appendix 2. It was applied to the different researchers, following a semi-structured format, asking the researchers to identify the key factors of biomass potential for energy purposes. In the last part of the interviews the researchers were to confirm if the key factors mentioned by other researchers like land availability, water, oil prices, resources competition are in their opinion key factors for the biomass potential. Their identification was complemented with a review of researcher papers, textbooks and legislation. The interviews include the authors of several research papers in order to gain a better understanding of the key factors. Subsequent to the identification of the key factors, the most recent studies about biomass are analyzed, in order to find to what extent the key factors are considered in the short and long term. The last part of the methodology is the analysis of these key factors in the short term (2010), as well as, in long term (2050). Moreover, the interrelations between the different factors and conclusion are done based on the analysis. The Figure 1-1 shows the methodology approach.

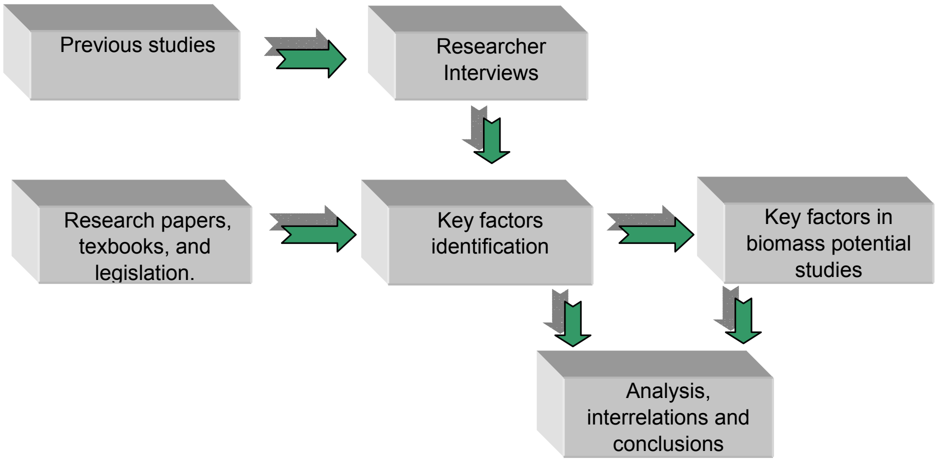

Figure 1-1 Methodology approach used in the research

1.5.2 Researcher Interviews

The interviews were conducted using a *semi-structured format*, which means topics are introduced and then the discussion is guided by asking specific questions. The information gained during the interviews led to using the *snow balling technique*[1], in order to get up-to-date and relevant information from experts and entrepreneurs. It was used more during the identification phase of the key factors in the long term.

Researchers with different perspectives involved in studies on biomass potential were really important to get a complete picture around the biomass potential. Their knowledge and preferences about the biomass resources and end-use give a mix of answers that lead to obtain valorous information to determine the key factors. Researchers from France, the Netherlands, Sweden, Finland, Germany, Greece, Poland, Ireland and Spain were interviewed. They are from different Institutions involved on national and international projects. Most of them are researches of the Bioenergy Network of the Excellence, (Bioenergy NoE)[2]. Others are the authors of some articles about biomass or CO_2 constraints. The summary of all researchers interviewed are in the Appendix 1.

1.6 Outline

The thesis is developed in six chapters. Each of them develops a specific, but also a complementary part.

Chapter 1: *Introduction*. It gives the preamble to the reader about the problem, objectives, scope, and limitation of this thesis. Further, it presents the methodology used to conduct this research.

Chapter 2: *Biomass Markets*. This chapter gives definitions for biomass and biomass potential. As well as outlining the framework of biomass markets. This is broadly divided into two sections. Section one provides a broader perspective on biomass resources. The second section provides information on the end-use of biomass for energy purposes.

Chapter 3: *Key factors for biomass markets*. This chapter is based on information collected through interviews and the literature review. It defines the key factors in the short term (2010) and in the long term (2050) for the potential biomass for energy purposes.

Chapter 4: *Assessment of different studies*. This chapter contains the assessment of European studies about the biomass potential. In the first part, it presents the biomass potential results of these studies. In the second part, it shows to what extent the key factors are considered in them.

Chapter 5: *Analysis*. The analysis of the key factors is presented. Both are considered in the short term and in the long term perspectives.

Chapter 6: *Conclusions*. This chapter presents the conclusions about the key factors for biomass potential in EU-15 and to what extent these factors are taken into account in the biomass studies.

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[1] Snow balling is an interview technique wherein you asked your interviewee for further relevant contacts for colleting information.

[2] Info on NoE www.bioenergy-noe.org

2 Biomass Markets

The use of biomass energy has increased around Europe. The demand for a most convenient energy carrier is growing in response to the rising oil prices. Both sides of the market, the supply and the demand of biomass are important to develop the market. The supply is represented by the availability of the different biomass resources, and the demand by the end-use of energy carriers like electricity, heat, and transport biofuels. Before developing these topics a definition of biomass and biomass potential is given, in order to get a better understand of both terms through the thesis.

2.1 Definitions

2.1.1 Biomass

Biomass needs to be defined to allow the harmonization of the policies and laws among countries and eventually to standardize the characteristics of all biomass types.

The European Commission Directive 2001/77/EC (Official Journal L 283 of 27.10.2001) defines biomass as: "Biomass shall mean the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste". In this Directive, it is not clearly indicated, if agriculture sources such as: short rotation crops and perennial grasses (energy crops) are included into the definition as products or what perennial grasses are included.

Besides, the Directive 2003/30/EC (Official Journal L 123 of 17.05.2003) defines "biofuels as liquid or gaseous fuel for transport produced from biomass". And it does not explain the definitions of biomass. This means that, it considers products from agriculture but it does not specify the agricultural crops, such as oil crops, woody crops, etc.

Council Regulation (EC) No 1782/2003 of 29 September 2003 establishing common rules for direct support schemes under the common agricultural policy and establishing certain support schemes for farmers and amending Regulations (EEC) No 2019/93, (EC) No 1452/2001, (EC) No 1453/2001, (EC) No 1454/2001, (EC) 1868/94, (EC) No 1251/1999, (EC) No 1254/1999, (EC) No 1673/2000, (EEC) No 2358/71 and (EC) No 2529/2001 define energy crops:

"Energy crops shall mean crops supplied essentially for the production of the following energy products:

(1) Products considered biofuels listed in Article 2, point 2 of Directive 2003/30/EC of the European parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport. It says at least the products listed are considered biofuel: (a) bioethanol, (b) biodiesel, (c) biogas, (d) biomethanol, (e) biodimethylether, (f) bio-ETBE (ethyl-tertio-butyl-ether), (g) bio-MTBE (methyl-tertio-butyl-ether), (h) synthetic biofuels (i) biohydrogen, (j) pure vegetable oil.

(2) Electric and thermal energy produced from biomass.

Besides, Commission Regulation (EC) No 239/2005 of 11 February 2005 amending and correcting Regulation (EC) No 796/2004 contains several definitions that need to be clarified.

In particular, the definition of "permanent pasture" and it is also necessary to introduce a definition for the term "'grasses or other herbaceous forage", as well as arable land.

"Arable land": shall mean land cultivated for crop production and land under set-aside, or maintained in good agricultural and environmental condition

"Permanent pasture": shall mean land used to grow grasses or other herbaceous forage naturally (self-seeded) or through cultivation (sown) and that has not been included in the crop rotation of the holding for five years or longer, excluding land under set-aside schemes pursuant to Article 6 of Council Regulation (EC) No 1251/1999.

"Grasses or other herbaceous forage": shall mean all herbaceous plants traditionally found in natural pastures or normally included in mixtures of seeds for pastures or meadows in the Member State (whether or not used for grazing animals).

The new definition of energy crops as is shown above does not describe the different species. It may be because the right crops for energy purposes are not identified clearly yet. They said that "by 31 December 2006, the Commission shall submit a report to the Council on the implementation of the scheme, accompanied, where appropriate, by proposals taking into account the implementation of the EU biofuels initiative". This will avoid the conflict between the industrial crops that can growth in the arable aside land and which only can growth in the set aside land. On the other hand, the new definition of the permanent pasture and grasses lead the cultivation of grasses in permanent pasture land for energy purposes.

2.1.2 Biomass Potentials

The understanding of the definition of biomass potential modifies the factors and outcomes in the calculation of the biomass potential for energy purposes. Hoogwijk distinguish five categories of potential (Hoogwijk et al, 2003):

The *theoretical potential*: is the theoretical upper limit of primary biomass; biomass produced in the total earth surface by the process of photosynthesis. Specifically, it includes the availability of forest wood, agricultural and commercial residues and all diverse sources of biomass.

The *geographical potential*: is the theoretical potential at land area available for the energy production using biomass and the productive level for energy crops.

The *technical potential*: is the geographical potential reduced by losses due to the process of converting primary biomass into secondary energy carrier. It considers only the engineering criteria, with few or any environmental considerations in the conversion efficient technologies. In the case of forest residues, it includes the technology associate to harvesting (Karjalainen et al., (2004)).

The *economic potential*: is the technical potential that can be realized at profitable levels depicted by a cost-supply curve of secondary biomass energy. Here the notion of economic potential are maintained instead use the financial potential, due to the inconsistencies in the definition used in different appraisals

The *implementation potential*: is the maximum amount of the economic potential that can be implemented with a certain framework, taking institutional constrains and incentives into account.

2.2 Biomass Resources

There are different ways to classify the sources. The simplest classification is by categories such as: energy crops, forest residues, agricultural residues, commercial industrial residues, biological wastes and domestic wastes. Each category is comprised by specific sources as are shown in Table 2-1. Unfortunately, not all studies use the same classification, making it difficult to compare their outcomes.

Table 2-1 Classification of the biomass and bio fuel resources

Categories	**Resource**
Energy crops	Perennial crops (wood and grasses)
	Sugar cane
	Maize and Sorghum
	Vegetable oils
Forest residues	Forest residues
	Timber by-products and sawdust sawmill
Agricultural residues	Temperate crops (Straw, potato, sugar beet tops, nursery, garden wastes, damaged fruit, and rape seed.)
	Tropical crop wastes, baggase (sugar cane fiber), rice husks.
Commercial and industrial residues	Paper industry
	Food
	Construction
Biological waste	Animal Wastes Dung (Manure from cattle, chickens, pigs).
	Sewage sludge
Domestic waste	Municipal solid waste (MSW).

The quantity available for energy purposes depends on the availability and the alternative uses. There is competition in the use of land for food production and feed crops, for pasture land, for forest land, and for residential and commercial purposes. At the same time, forests can be used for timber and pulp and paper industrial purposes, energy production or just left as forests. Additionally the residues from industries can be used to produce wood based panels or for energy production. The residues from agricultural crops can be used to produce feed and fertilizers. The combination of all these possibilities in the regional context gives the total availability for the different sources of biomass.

2.2.1 Energy Crops

The increasing interest in bioenergy has allowed testing new agricultural crops. Willow and Poplar have been tested since 1970 and some perennial grasses since 1980. According to studies in USA and EU, the most promising energy crops are: Switchgrass, Miscanthus, Giant reed, and Reed Canary grass. Willow (Salix) is the most profitable agricultural crop in Sweden (Larsson, 2005). Switchgrass and Miscanthus are grasses with a C4 photosynthetic pathway. While Giant reed and Reed Canary grass are grasses with a C3 photosynthetic pathway. In temperate and warm regions, C4 grasses out yield C3 grasses due to the more efficient photosynthetic path way (Lewandowsk et al, 2003). In C3 the additional energy demand for photorespiration reduces the photosynthesis efficient by 15%-30% (Sandquist, 2005).

The qualities of the biomass give advantage in their potential applications. Its low content of water is favorable for use as solid fuel. In general energy crops produce less emission (CO_2, NOx, SO_2) than forest residues and other energy sources. This is show in Table 2-2. Besides, the C4 Switchgrass in relation to C3 reed canary grass has less content of ash, N, K, and minerals, also this can be assumed like a general characteristic of C4. On the other hand, the gross calorific value in C4 is less than in C3 (Lewandowsk et al, 2003). Also, it is important, to take in consideration the average quantity of nitrogen required by each energy crop, preventing the excess content, in order to avoid the emission of NOx in the combustion process, or in general in any end-use purposes.

Table 2-2 Net cycle emissions from electricity generation in the UK.

Technology- Fuel	**Emission g/kWh**		
	CO_2	**SO_2**	**NO_x**
Combustion, steam turbine			
poultry litter	10	2.42	3.9
straw	13	0.88	1.55
forestry residues	*29*	*0.11*	*1.95*
MSW	364	2.54	3.3
Anaerobic digestion, gas engine			
Sewage gas	4	1.13	2.01
animal slurry	31	1.12	2.38
Landfill gas	49	0.34	2.6
Gasification, BIGCC			
Energy crops	*14*	*0.06*	*0.43*
forestry residues	*24*	*0.06*	*0.57*
Fossil fuels			
Natural gas: CCGT	446	0	0.5
coal: best practice	955	11.8	4.3
coal: FDG &low NOx	987	1.5	2.9

Source: Boyle (2004).

Another energy crops are the oil crops and the crops for fermentation. Rape and sunflower are considered the most promising oil crops. They are grown in Europe for food oil. Besides, both are used for biodiesel production. On the other hand, sugar beet, grain of cereals like wheat, barley and rye, as well as, sorghum are used to produce ethanol by fermentation or by transformation of the cellulose materials. The sugar beet is used for sugar production, and the cereals for food. However, they use them for energy purposes although their cost is higher.

2.2.2 Forest Residues

One of the main sources of bioenergy production is forest residues. The harvesting process is intended mainly for industrial production, secondarily for energy production and finally for forest production. Besides, the residues produced in the harvesting process can be significant, as well as the residues from the industry process. The principal industry processes are timber industry, pulp and paper industry. The alternative use is the fabrication of wood-based panels and energy production, e.g. pellets and briquettes. In each region the availability is different, depending on the existing forests, the felling and the residues from industrial production. In Sweden and Finland forest cover half of the territory, while in other areas like The Netherlands or Denmark forests cover only 10% of the country. The forest area has not changed in the last decade and it will remain unchanged in the future, according to the European Commission statistics and Food and Agriculture Organization, FAO.

2.2.3 Agricultural Residues

Another source is agricultural residues. It depends on the crops in the region. The competition between these resources is high. It can be used either as a raw material to produce feed for animals or as fertilizer. The majority of the residues come from cereals such as: wheat, barley, rye and oats. Straw is the most abundant crop residue, which is used for energy purposes. The regions with more agriculture productive in cereals are: Southeast of England, France, Belgium, The Netherlands, Luxemburg and Germany; for that reason they are the areas with more agricultural residues.

2.2.4 Commercial and Industrial Residues

The most common commercial and industrial residues come from paper industry, construction and food consumption. The residues from paper industry are reused again into the process or sometimes they are taken into account as forest residues. Demolition wood is used again in the construction process and sometimes also as a source of energy. The food residues are used to produce feed. Much of these residues are mixed with domestic wastes and therefore they are considered municipal solid waste. This is one of the most difficult categories to identify in the majority of the studies.

2.2.5 Biological Wastes

Animal manure from pigs, cattle, chicken is the most common wet waste. Some farmers use this to produce biogas through anaerobic digestion. Others use it as fertilizer for agricultural crops and pasture land. Biogas production is done more in UK while other European countries are really low.

2.2.6 Domestic Wastes

Millions of tonnes of domestic waste are produced each year. Proper waste separation allows recycling, composting, incineration and land filling. Many industrialized countries consider refuse incineration with heat recovery an important mean of waste disposal. However, there are others, who produce biogas through anaerobic digestion.

These three last categories have special constraints in Europe. Fuel like manure, slaughter house waste, waste from pulp and paper production, biodegradable municipal waste and sewage sludge are regulated by three directives: Directive of the incineration of waste (2000/76/EC), Directive on the limitation of emission of certain pollutants into the air from large combustion plants (2001/80/EC) and Directive on the landfill waste (1999/31/EC). The strong regulative role of waste management policies makes these categories non-tradable fuels (Siemons et al, 2004).

2.3 Biomass End-uses

The European Union countries have promoted many actions and goals around the role of the biomass to produce electrical and thermal energy (heat and cool) and biofuels for transport.

2.3.1 Electrical Energy

Current trends definitely point in the direction of ever increasing *electrical energy* use with a level of consumption in the EU that could increase by 10% in the coming 15 years. Furthermore, faced with increasing oil prices and the prospects of having 70% of its energy needs covered by imports by 2030, the renewable energy sources (RES) have been promoted (European renewable energy industry, trade and research associations, 2005). Biomass with a share of 62% of the total renewable energy is the biggest renewable energy. The Biomass-based electricity is promoted through the Green Electricity Directive, aiming to increase the use of electricity from renewable from 14% to 22% by 2010 (Directive 2001/77/EC on renewable electricity). It is shown in the figure 2-1, each state member has a specific target. Each state has adopted national legislation in order to develop the internal electricity market. The Directive set a minimum targets for the opening of the market which corresponded to 30% on the consumption in 2000 and 35% in 2003. This opened the possibility for the biggest consumers to choose their supplier freely (Alakangas and Vesterinen, (2003)). Member States have different means at their disposal to support renewable energy sources, such as electricity feed-in tariffs, green certificates, market-based mechanisms, tax exemptions etc.

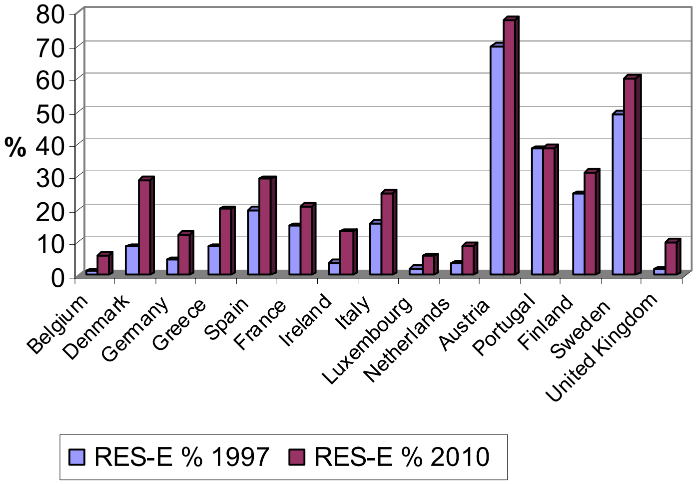

Figure 2-1 Electricity production by RES(%) in Europe in 1997 and indicates goals for electricity production in 2010.

2.3.2 Thermal Energy

On the other hand, the production of *thermal energy*, which involves heating and cooling, has been promoted too. Especially through the Directive 92/42/EEC [Official Journal L 52 of 21.02.2004] for cogeneration, this has the purpose of increasing the energy efficiency. The scheme, to promote it, is the public support for cogeneration based on economically justifiable demand for heat and cooling. This is the case of Sweden and Finland, where district heating provide over 40% of the building heating, especially in highly populated areas. The local authorities are the owners and planners of the heating system. The cogeneration of heat and power, CHP, in Finland is the highest in the world. They produce 80% of the heat by CHP. However, small scale heating is necessary in rural areas. Wood is used in burning stoves, but the pellets users have developed a great demand, because of its low emissions pollutants. Member States operate different mechanisms of support for cogeneration at the national level, including investment aid, tax exemptions or reductions, green certificates and direct price support schemes.

2.3.3 Biofuels for Transport

The Commission White Paper "European transport policy for 2010: time to decide" expects CO_2 emissions from transport to rise by 50 % between 1990 and 2010, to around 1113 million tonnes, the main responsibility resting with road transport, which accounts for 84 % of transport-related CO_2 emissions. From an environmental point of view, the White Paper calls for the dependence on oil (currently 98 %) in the transport sector to be reduced by using alternative fuels such as *biofuels*. The transport sector accounts for more than 30 % of final energy consumption in the Community and its percentage is expanding. The Commission Green Paper "Towards a European strategy for the security of energy supply" sets the objective of 20 % substitution of conventional fuels by alternative fuels in the road transport sector by the year 2020. Until now the 2 % have been achieved in 2005 and the 5.75% is expected in 2010. The biofuel market depends on the availability of resources and raw materials, on national and Community policies to promote biofuels, on tax arrangements, and on the appropriate involvement of all stakeholders/parties, according to Directive 2003/30/EC.

3 The Key Factors for Biomass Markets

To better understand, key factors are issues of great importance to increase the actual use of bioenergy in the short and long term. These key factors rely on in sub-factors due to the complexity of each of them. In the short term the production and use of energy carriers base on RES need to be tested. Important learning processes for further development are necessary. The learning processes involve experience in the use of technologies, experiences relate to relevant actors, as well as, the development of the actor's network. In the short term the local capability and the improved supply chain coordination are important. In the long term other key factors for the large scale introduction of bioenergy include: Land uses, efficiency, price competitiveness, climate change, policies, Integration. All of them are explained in the following paragraphs.

The starting point is to know if the key factors that were identified in the previous studies are still valid as key factors in the biomass potential. The previous studies had identified the most important barriers and drivers for bioenergy market growth, according to the focus on production structure and market structure. In the case of Roos, it has been taken from five cases, which were not successful stories, in some aspects. However, it offered a framework to develop projects to achieve the competitiveness, increasing the *productivity* for all factors of production, to reduce the *cost,* and to make successful marketing with low *transaction costs*. The identified key factors were: (1) Integration, (2) Scale effects, (3) Competition in the bioenergy sector, (4) National policy and (5) Local policy and opinion (Roos et al, 1999). In another study Hezik and Madlener identified socio-economic and institutional barriers. The institutional barriers are: (1) Lack of the capacity to develop or to evaluate sound project proposals, (2) Lack of personal skills, (3) Unsuccessful planning, (4) Lack of cooperation with other governmental bodies, (4) Lack of the information or poor communication. Besides, some socio-economic barriers were identified as: (1) Characteristics of the community, (2) Scale effects, investment cost and/or service and maintenance cost are considered to high, (3) Inefficiency due to overregulation, (Hezik and Madlener, 2003)

3.1 Short Term Key Factors and Sub-factors

The key factors are gathered from the interviews with researchers who have developed studies around the biomass potential or specific projects regarding biomass. These interviews allowed to find some of the key factors identified in the previous studies still remain but with different characteristics. The key factors identified in the short term are local capacity or developing successful projects and supply chain coordination. Both are interrelated, as is shown in the Table 3-1.

These key factors are important for energy crops and forest residues, although it is more urgent to conduct a research on energy crops production. Due to, it has more potential in the long term. The outcome of short term key factors gives useful information regarding environmental evaluation and techno-economic evaluation for the definition of the key factors in the long term.

Table 3-1 Key factors in the biomass potential in the short term, (2010).

Factor	Sub-factors	Energy crops	Forest Residues
1. Local capacity	*- Pilot projects,*	x	x
	- Information and dissemination	x	x
2. Supply chain coordination	*- Promotion*		
	= Biomass sources	x	x
	= Customers to electrical and thermal energy and biofuel.	x	x
	= Acquire technology from abroad.	x	x
	= Market development	x	x

3.1.1 Local Capacity

The local capacity refers to the availability of developing successful projects around of the biomass. It refers to the knowledge to implement pilot projects. These projects overcome the barriers identified in previous studies and take advantage of the drivers of the previous studies. Besides, the dissemination of the project's outcome plays an important role in order to get the acceptance and support of the biomass.

Pilot projects

Pilot projects cover energy crops production, biomass processing, logistics and biofuel production from lignocellulosic biomass. Development of pilot projects was identified as the one with highest importance in a recently EU study about the possible actions to promote Bioenergy Market development in EU (European Union Biomass Plan, 2005). This study identified the specific needed actions in order to increase the biomass availability, to eliminate market barriers for power, heat and CHP generated by biomass, as well as biofuel; also, how to promote business development for the biomass market actors. However, these factors have been worked on different projects through the different national and international organizations.

The pilot projects, which are running now, are designed to solve the barriers showed in previous studies of Roos et al. (1999), Hezik and Madlener, (2003) and Rosch and Kaltschimitt, (1999). As well as, they take advantage of the previous successful experiences from other cases. The following projects are good examples of the current actions around this aspect:

One project is: "Bioenergy Chains from Perennial Crops in Southern Europe". This was developed by a consortium of 9 institutions: CRES from Greece, ASTON from UK, VT-TUG from Austria, UPM from Spain, INRA from France, UNIBO from Italy, BTG from The Netherlands, AUA from Greece, IFEU and IUS from Germany.

The overall objective of this project is to evaluate, in terms of technical, socio-economic and environmental feasibility, the whole bioenergy chain from the biomass production to the thermo-chemical conversion for a number of perennial energy crops (Cardoon, Giant reed, Miscanthus and Switchgrass) were carefully selected to ensure, by successive harvesting, a year around availability of raw materials.

The thermo-chemical conversions include fuel characterizations, combustion tests, pyrolysis tests and gasification tests.

The economic and financial assessment covers the cropping systems, transport, supply and energy generation and analysis of all direct and indirect energy costs (and carbon costs) associated with growing the crops, harvesting the crops and generating the electricity. Finally, the financial analyses cover all combinations of crops in each site. The environment impact assessment is done using tools such as life cycle assessment (LCA) and environmental impact assessment (EIA). The outcome will be the identification of the best options of bioenergy resources and technologies in monetary, social and environmental terms (Christou et al, 2002). This project has been running from December 2001 to the end of 2005. The duration is 48 months, which means that the results will be available soon.

Another project which was started more recently and includes more variables is: "Bioenergy Research – French Program" from 2004 to 2009. It is national and covers the whole chain. The stakeholders involved are: farmers, forest experts, agricultural and technical research organization, biofuel producers, the automotive industry, and the mineral oil industry. There are 26 organizations working together. The project was developed in four modules (Programme national de recherche sur les bioenergies, (PNRB), 2004).

(1) Production and mobilization of the biomass lignocellulosic resources. It covers the technical, economic and environmental evaluation of the different resources such as: agricultural residues, perennial crops, short rotation crops and forest resources. Besides, it includes the determination of the quality of the resource for the technology transformation from primary resources to secondary carriers, the anticipated study of the wood markets and the evaluation in the short term (2010) and in the long term (2020) of different scenarios.

(2) Thermo-chemical conversion of the biomass lignocellulosic. It includes: Developments in pyrolysis, gasification and combustion. The techno, socio-economic, environmental evaluation of these technologies, and the design of the engineering platform is being evaluated in order to launch and apply it in other biomass projects. The results will consist of different technology options, the operation conditions and the capital costs. It will be completed in 2009.

(3) Biological conversion of the biomass lignocellulosic. The pilot program will be carried out primarily in the scale of the laboratory and the small pilot, on the first four years, with the goal of improving the techno-economic feasibility. The technical project includes: quantity and quality of the resources, design and production of scarification enzymes, enzymatic hydrolysis, ethanol fermentation of the hydrolase, distillation, integrating process and assessment of the life cycle assessment. The studied resources will be the straw or cereal residues.

(4) Techno, socio-economic and environmental evaluation. Establish a comparative assessment of the data from the different modules. The first evaluation is the techno-economic evaluation and the second is the environment evaluation. The results will improve the confidence of the assessment at the national and the international level.

There are others project running now. According with Lewandowsk there are other pilot project in biomass in Germany, due to the great interest of the automobile industry in biofuel for transportation.

Information and dissemination

The dissemination of information from the pilot projects is the subsequent step after the development of the projects. The dissemination of the outcomes should be provided to the different stakeholders, in order to get the acceptance and adoption of biomass for energy purposes accomplished more effectively. One way to fill this purpose is the establishment of an information center, which allows access to the information regarding biomass benefits. Another dissemination mechanism is through publications in scientific and trade journals, as well as, presentations in international conferences. This should be complemented with campaigns regarding the socio-economic benefits of the biomass for common citizens. Furthermore, a lot of projects have received local support, mainly because they generate local jobs and economic inputs. A favorable attitude in the local community helps the bioenergy projects in several ways: expending permits, improving public relations, increasing local demand. The visit to the experimental field by decision making groups, local authorities, local agriculture, energy organization and farmers give a real dimension and knowledge about the biomass.

On the other hand, campaigns for farmers and forest owners can help to start to the production in the large scale. One of the disadvantages that have been mentioned by the farmers is that the results are from experimental projects, but not from real experience in the large scale. Passing from experimental pilot projects to the research applications, which means scaling from 1-10 ha to 100 ha, overcomes these barriers. It is the case of French National Bioenergy Program, which will give enough information about the financial aspects, as well as, the organic considerations that farmers should apply during the growing process of the crops. The farmer's confidence to star this kind of crops plantation in an industrialized scale is the most important aspect in the short term.

3.1.2 Supply Chain Coordination

It refers to the producers, users, technologies industries and market actors, which act interrelated, creating a system in order to supply biomass resources for an energy purposed project. Other study refers to the same factor as cooperation (European Union Biomass Plan, 2005), and Kåberger, 2005 refers it as supply chain completeness. This factor was one of the drivers for previous cases. The use of existing structures such as machines, infrastructure, know-how, and dealer networks etc., as part of the integration, as well as the integration of the different actors. This integration can be used to get cheap inputs regarding the biomass supply and infrastructure, as well as, reducing the transaction costs and risks. The current successful examples use fuel such as by-product from logging, forest industry or from the agricultural sector. In Maine, U.S., the contractors collecting the forest fuel normally have a forest sector background and in Sweden the fuel trade is organized by forestry companies. The pellet industry in the United States is integrated downstream to an infrastructure of stove and pellet fuel dealers for the distribution and marketing tasks. In the Austrian case, the biomass heating plants often rely on the integration of one local supplier for the biofuel. The district heating projects in Austria are often integrated with other village community activities and their successes rely on the community spirit in the village. All cases show different ways of taking advantage of the existing resources and structures in the bioenergy industry.

A new approach to integration is the supply chain coordination. This factor is presented in the following three steps:

The first step is the *development at the same time of the supply and the demand.* The supply must provide enough resources to satisfy the demand of the customer for heat, electricity and biofuel for transportation. The demand for heat is the district heating, for electricity the grid and for biofuel is the automobile industry. If they are not developed simultaneously, the farmers say that it won't be able to sell their yield or specifically they will not be enough buyers. Besides, it is the same situation for the owners of the bioenergy plant, who state that if they set up a bioenergy plant, they do not have enough supply of biomass resources. Taking in consideration that the resource from agricultural residues, forest residues and industrial residues are the most important in the short term according to Ericsson, 2005 it can be enough in the beginning to start biomass projects.

The second step, after addressing the supply and demand, is to *acquire the technology plant* even from outside countries by the plant owners. Finland and Sweden have high development in this technology and also experience in the commercial operation of them. Combustion, pyrolysis and gasification are the technologies which have been developed to provide thermal and electrical bioenergy, as well as, biofuels.

The third step is to start the demand and consequently the *market growth*. The promotion of the market implies to develop a professional, large-scale international market floor for biofuels: wood chips, liquid biofuels and pellets. While the market is still "new", the transaction costs are higher, i.e. the costs for market research, measurement, negotiation, contracting and contract enforcement.

As the business grows, technical innovations and organizational solutions are normally found, increasing productivity and reducing costs, including transaction costs. Besides, the expansion of quality standards improves market efficiency; feedstock deliveries and thus, generating further innovations. To achieve these growths more biomass resources are needed.

These successful projects of supply chain coordination must reply in other regions, in order to increase the number of biomass appliances. Besides, it must provide profit to all stakeholders in each replication. Furthermore, the income is related to the learning curve in each case. For that reason, both, local capacity and supply chain coordination are the key factors in the short term. They help to support the start of the biomass market in a region where no previous projects existed and support the development in areas which already have biomass projects. There are other factors contributing to the biomass potential in the long range which are developed in the section 3.2.

3.2 Long Term Key Factors and Sub-factors

There are factors that influence the biomass potential to 2050. They are considered factors in the long term, which are likely influence the potential growth. Their definition and action plans must be set in the short term, but their effects will be noticeable in the long term. The key factors that were identified are: (1) Land uses, (2) Efficiency of yield, conversion technology and end-use. (3) Price competitiveness. (4) Climate change (5) Policies (6) Integration. All these factors are shown in the Table 3-2 and are described in this section.

These long term factors could be included of the short term. Moreover, when there is already land to produce energy crops and policies around biomass potential which have been boost the biomass. However, the outcomes of the pilot projects are prerequisite in order to know what are the right crops, the techno-economic evaluation and the environmental evaluation around the supply chain of biomass. It is in order get enough information and knowledge to redefine the policies and economic instruments around biomass.

The key factors, in the long term, will affect energy crops and forests in similar way, as is shown in the Table 3.2. The minimum differences are explained in the description of each factor. The efficiency plays and important role for energy crops, while the competition of the resource for other purposes plays a significant role in forest residues.

Table 3-2 Key factors for the biomass potential in the long term, (2050).

Factor	Sub-factors	Energy Crops	Forest Residues
1. Land uses	*Population growth and consumptions patterns*	x	x
2. Efficiency	*Yield/water*	x	
	Harvest ratio		x
	Conversion technology	x	x
	End-use	x	x
3.Price competitiveness	*Resource competition*		x
	Biomass/biofuel market and prices	x	x
	Rising oil prices	x	x
4. Climate change	*Global hydrology- Water.*	x	x
	Effects in the crops physiology, yield and forest.	x	x
5. Policies	*Integrated policies,*	x	x
	National and local policies and legislation and promotion.	x	x
	Taxes, subsides and other support scheme	x	x
6. Integration		x	x

3.2.1 Land Uses

There is competition in the use of land for food production and for animal feed crops, for pasture land, for forest and fiber land, and for residential and commercial purposes. The land in Europe is divided in different categories according to their use: (1) Agricultural land, (2) Forest and wood land. (3) Other uses such as: residential, commercial, transportation and (4) Unused land such as: fallow, bare and mountains. This definition had been detailed by different EU Council regulation, as shown in the section 2.1.1., in the definition of Biomass. Table 3-3 shows the share of used land in Europe, where agriculture and forest land combined represent around 71% of the total land area.

Population growth and consumption patterns

The usage of the land will change due to the population growth. People will need more land to build upon and therefore they will need more global arable land to produce food. European food consumption patterns show large differences in the consumption of specific foods. Consequently, it creates large variations in the agricultural area required. For example, Portugal shows the smallest requirement, 1814 m^2 per capita per year, and Denmark the largest, 2 479 m^2 per capita per year (Gerbens-Leenes and Nonhebel, 2005). The trend toward food consumption associated with comfortable life styles will bring the need for more land.

Table 3-3 Different categories of land use among the EU-15.

Use	**Definition**	**Km²**	**Percentage (%)**
Agriculture	The sum of arable land, permanent crops and permanent pastures and meadow.	1 343 180	41
Forest	Land under natural or planted stands of trees, whether productive or not.	972 945	30
Other Uses	Land for residential, commercial, transportation and leisure purpose.	320 398	10
Unused	Land without any apparent or specified uses such as fallow or bare land and mountain.	603 630	19
Total		**3 240 160**	**100**

Source: European Commission. (2005d). The Lucas Survey: European statisticians monitor territory.

The land required for food production has been calculated as 0.24 ha/cap (see Ericsson and Nilsson, 2004). This calculation is based on per capita consumption of 20 commodities in EU15 for 1995, including importing and imported commodities. Multiplying these data by each commodity's claim on land produces an EU mean of 0.24 ha/capita. The global availability was 0.25 ha/cap of arable land and permanent crops for food in 2000, while the population was around 6.1 billion. With the population rising to 9 billion, around 2050, the availability of land to produce food will be 0.17 ha/cap. Besides, if it includes the area used for permanent pasture, 0.82 ha/cap was used in 2000, and it will be 0.55 ha/cap in 2050 (Wuppertal Institute and Science Centre North Rhine Westphalia, 2003). On the other hand, *forest land* and nature conservation areas keep equal or increase depending upon the policies in each country. However, the requirements for agricultural land are increasing in the EU due to the need for more renewable material and supply of biofuel. The fiber consumption pattern is rising. Total worldwide demand for fiber (cellulosic, cotton, wool, man-made, others) is predicted to increase from approximately 50 million tonnes/year (1999 figure) to 130 million tonnes/year by 2050 (in line with the predicted growth of the world's population) (Ienica, 2005). Furthermore, the productivity per hectare will decrease, if farmers move to eco-farming, because they will be required to use the resources in a sustainable way. At the same time, the new accession EU countries enlarged the agricultural land and they must achieve the same productivity in their yield than the west Europe countries. All these requirements and relations around the land availability are shown in the figure 3-1.

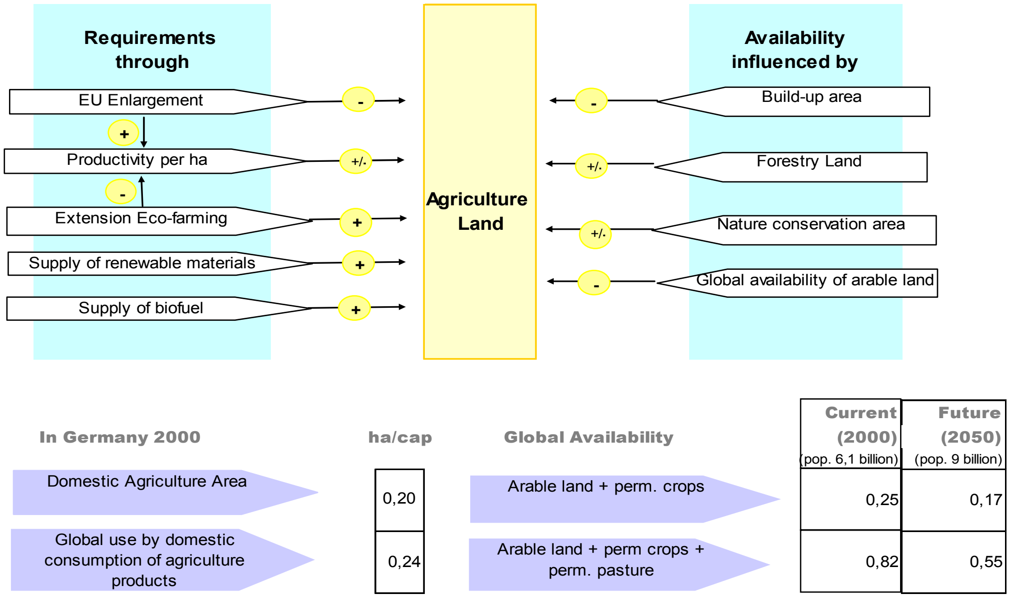

Figure 3-1 Increased and Conflicting Requirements for Agricultural Land. Source: Wuppertal Institute and Science Center North Rhine Westphalia (2003).

Regarding the set aside land for energy crops, the farmer shall declare the parcels corresponding to the eligible set aside land with payment entitlements. Eligible areas shall mean any agricultural area of the holding taken up by arable land and permanent pasture except areas under permanent crops, forests or used for non agricultural activities. It may be subject to rotation. A maximum guaranteed area of 1 500 000 ha for which the aid may be granted is hereby established. The basic rate of compulsory set-aside is fixed at 10 % for the marketing years 2005/2006 and 2006/2007. However, countries like U.K. fixed the compulsory set aside land at 8% (Defra, 2005), and Sweden at 7.5 (Nilsson, 2005). This suggests that each Member State establishes its own rate. These rates have decreased due to severe drought and low harvest in the main cereal production regions of the Community (European Commission, 2005a). Besides, now 5% is compensated for the drought conditions in southern Europe and the consequential fall in harvest levels. If energy crops are grown on main agricultural land, there is an additional aid of 45 euro/ha, besides the Member States shall be authorized to pay national aid up to 50% of the costs associated with establishing multiannual crops intended for bio-mass production on set-aside land (According to Article 71, Europe Commission, 2004).

Crops considered multiannual are: "(1) artichokes, (2) asparagus, (3) rhubarb, (4) raspberries, blackberries, mulberries and loganberries, (5) black, white and redcurrants and gooseberries (6) cranberries, bilberries and other fruits of the genus Vaccinium, (7) short rotation coppice (SRC), (8) miscanthus sinensis (elephant grass), and (9) phalaris arundinacea (reed canary-grass)". (Commission Regulation (EC) No 795/2004 of 21 April 2004).

According to the definition of multiannual crops, some resources or species to produce biomass for electricity, heat and biofuel for transportation are included into the definition, but not all of them. The council Regulation states that by 31 December 2006, the Commission shall submit a report to the Council on the implementation of the scheme, accompanied, where appropriate, by proposals taking into account the implementation of the EU biofuels initiative. Furthermore, by 31 December 2010 at the latest, the Commission shall submit a report on the application of the farm advisory system, accompanied, if necessary, by appropriate proposals with a view of rendering it compulsory (Council Regulation (EC) No. 1782/2003 as amended, Commission Regulations (EC) Nos. 795/2004, 796/2004 (both as amended) and 1973/2004).

On the other hand, the Department for environment, food and rural affair, Defra, of U.K states "One effect of this derogation is that these farmers may now have more land considered "arable" on both 15 May 2003 and 15 May 2005 have more land that is "eligible for set aside" (and that may contribute to a larger set-aside obligation) than they would have otherwise have had". Definitively, this is a transition period around the set aside land issue. It will depend on the proposal of the biofuel initiative to be made on December 2006.

3.2.2 Efficiency

When the demand is introduced in the study of the biomass potential, it is necessary to consider the efficiency. It has to be considered in the yield, in the conversion technology and the end-use. The efficient operation is measured by a comparison of production with costs.

Yield efficiency

Reliable statistics on yield will be available through the outcome of the pilot projects. Some of them are similar to the farmer's scale, (100 ha), allowing confidence in their results. However, the detailed results will not be available until some years in the future. The maximum yield will be the result of the learning process, base on the experimentation in order to know the optimal conditions for each crop. The right selection of energy crops assurances higher yield (Gisland, 2005). The yield depends on the light and water availability, some times the temperate and soil constrains are important too (Lewandowsk, 2005).

The right selection must balance the soil carbon with the ecologic balance. This balance is represented by the use of fertilizer and impact into the soil. The ecological advantages of the long periods without tillage reduce the risk of soil erosion and increase the soil carbon (Lewandowsk et al, 2003). The most favorable energy crops are the perennial grasses like Miscanthus, Switchgrass, Cardoon, etc. which are harvesting annual for that reason do not represent any problem compare with the food crops. The key factor in the perennial grasses is to get the balance between their productivity and the environmental impact. To determine the environmental impact is important to look behind the management practices such as fertilization and recycling of nutrients (ashes). Furthermore, pest control will be necessary since the second year, although there are not current reports of plant diseases significantly limiting the productivity of the perennial grasses. These aspects should be part of the deployment in the farmers scale. Farmers should adopt the organic perspective in the production of energy crops using machines and avoiding the intensive man labor. It is in order to get a sustainable development with a reasonable efficient. However, the use of unemployment labor can be evaluated in order to know the benefits and cost around it.

Other factor to be considered is the different *ecological and climates zones*, e.g. the Switchgrass out yield Miscanthus in sandy soil with occasional drought, but when Miscanthus is in heavy soil and better water supply the opposite is observed. The cold in the north of Europe made less species suitable. The warm climate and lack of water in the south of Europe is a limitation for other species.

In some of Sweden's municipalities *the fertilization* is done by using sewage sludge; Örebro and Västerås are two of the large cities supplying sludge to willow plantations. This could reduce the water and fertilizer requirements. The *water* is the mayor limiting factor for energy crops production, principally in southern Europe, and it is the most important factor which determined the yield. For example, the peak yields of Miscanthus, when nutrients and water are not limited (irrigation), is 42-49 t $ha^{-1}y^{-1}$ (odt) in France and the yield falls down to 18.8 – 20.5 t $ha^{-1}y^{-1}$ (odt) with rainfed exclusively (Tayot et al 1995). It represents a yield variation of more than 50% when is irrigated. In practice, however, it could be too expensive to fully irrigate biomass crops in drought-prone regions. In the estimation about water required for bioenergy, Berndes states "if the biomass is harvested, dried, and combusted for electricity generation at 25 percent efficiency, a moisture content of 50% in fresh biomass corresponds to about 0.2 Mg water per GJ electricity generated. And this is roughly a factor 50 or more below the estimated energy crops evapo-transpiration". Besides, the rainfed biomass production can redirect water runoff to evapo-transpiration, affecting the areas with scarcity of water (Berndes, 2002). The water is considered part of the yield. It is not considered an individual key factor for biomass potential. However, the water is treated largely in climate change, as a key factor, in regard to the change in the global water and competition for water supply due to the use and abuse of it.

On the other hand, growing different mixtures of energy crops allows supplying the heating and power plants to regularly change sources due to the different *harvest time* of each energy crops. It reduces the storage need, and the associated cost. The total *cost* is a function of the establishment, management and harvest of the crops. The critical factor for the cost is the yield by hectare.

The development of *new crops varieties* and the improvement of the existing crop's characteristics are needed. It is especially needed in the adaptation of droughts-prone areas. The annual growing of grasses allows this result faster than in energy wood crops or short rotation crops. The improvement of a new variety has to be tested for at least in two generations. This process takes around 10 years for the willow (Larsson, 2005) and for the grasses around 2-8 years.

Harvest ratio

Harvesting forest residues can cause soil depletion, since fewer nutrients are completing the cycle. Low harvest ratio takes into account the ecological conservation, while the high ratio can only apply if the ashes are recycled in order to compensate for the loss of nutrients (Ericsson and Nilsson 2004). On the other hand, the fraction of by products available for energy purposes is 25%. This is an approximation, but a lot studies show the same value in this issue.

Efficiency in the conversion technology

The production of different crops is integrated with the type of energy conversion. In the pilot projects perennial grasses were tested by ASTON from UK using pyrolysis test, VT-TUG from Austria by combustion test and BTG from The Netherlands by Gasification test. In the France Program, VTT are testing these materials in order to determine which quality characteristics are suitable for the different conversion process.

Perennial grasses can be used in the combustion technologies to produce thermal and electrical energy. These are C4 photosynthesis way. C4 in relation to C3 has less content of ash, N, Cl, K, and minerals offering advantages in combustion process. Besides, research in perennial grasses shows that they can be used to produce methanol and ethanol in the large scale through the gasification and pyrolysis in the next 10 years (Lewandowsk, 2005). Not only the technology conversion needs to be developed, besides silos for storage of the feedstock material is required. Due to the factor that harvesting windows for short rotation crops (SRC) is 4 months and for perennial grasses it is around 2-3 months. Additionally, it must be stored at 20% moisture content in order to assure the conservation of the biomass characteristic and the permanent supply of biomass around the whole year.

Gasification is one of the technologies with more possibilities in the long term, because it can transform biomass in CO+ H_2. These gases are converted into gas oil for e.g. by the Fischer-Tropsch synthesis. Thus, around 2050, hydrogen could be used to feed a fuel cell. It should be developed in large scale to produce biofuels due the large demand and expected cost production reduction (Gisland, 2005).

The initial consensus was to use biomass for heating and for cogeneration instead of producing biofuel for transport. It is because the efficiency in thermo-chemical conversion to produce heat is bigger. The conversion efficiency for heat is around 95%, for power plant is 50% , for cogeneration plants 90% and for biofuel 20-50% depending of the technology. This means that it possible to get more CO_2 reductions when using 1 GJ of biomass for heating than if converted into, methanol, and used for transport. When the studies are considering to produce biofuel in the long range, biomass turns out to be the economically preferred option in the medium term, around 2050. In the long term, R&D will continue developing of the hydrogen production and storage for the transportation sector (Azar et al 2003).

On the other hand, there are current technologies which use natural gas, which require re-conversion in order to use biomass. This requires an extra investment cost. Besides, the adaptation of the technology needs also to handle biomass material as feeding system.

End-use efficiency

The interest to use biomass depends on the sector, large energy plant want it to produce electricity, while the rural areas in cold climates want to use the biomass to produce heat and the automobile industry wishes to use biomass to produce biofuels (Rogulska, 2005).

Although the highest efficiency of the cogeneration, which is around 90%, the cost of the electricity is higher compare to the nuclear or hydropower electricity cost. Moreover, the cogeneration produces more heat than is demanded. Subsequently, the efficiency drops significantly when producing only power.

The production of heat through the district heating in the densely polluted areas is less expensive than if it is produced from natural gas, as is the case of Denmark. If the resources are available in the region the costs are lower compare to the cost of transportation from long distance (more than 100 km). The district heating has high-energy efficiency, low emission and fuel flexibility compared with the individual heating systems. Conventional firewood heating systems have relatively high levels of emission of pollutants with negative health effects. Consequently, fuel quality is important and changeover to the pellets is a trend at the family level. The developed market for pellets has made important the distribution network. However, the secure supply of heat by the district heating is higher compare with pellets offered.

In the transportation sector there are different projects supported by the EU, where the national governments are working closely with the automobile and fuel industries, vehicle users, consumers and environmental stakeholders, in order to promote the development and introduction of new vehicle technologies. The active participation of the automobile industry in the pilot projects assures the customer demand in the future of biofuel. The customers want to increase the efficiency of their engines and to protect the environment. Concrete results from the pilot project phase must be communicated in order to inform all stakeholders about the advantages of biofuel in the transport sector. It should be done in order to overcome the local misconception, for example in Poland, where the private car drivers do not want to change the fuel for their engines, because they have the perception that biofuel is not as good as oil fuel.

3.2.3 Price Competitiveness

The coordination of the supply chain and the local development and capability of using resources of the region to satisfy the demand is very important to the short time. Moreover in the long term, the demand is the most important factor. If there is more demand for biofuel for transportation instead of heating uses; then, it will be used in the sector which has more demand. In the case of France and some southern countries in Europe, they want to produce biofuel instead of producing electricity; because biomass are not competitive compare with nuclear or hydroelectric power. This means that the prices are influenced by resource competition, biomass/biofuel market and rising oil prices.

Resource competition

The resource competition is clear, because the potential supply is not enough to cover the demand in all sectors. Years ago, industrial waste had negative price, now it has changed. Forest residues and by-products from the industry are one of the sectors with more competition. There is higher demand for sawdust to produce wood chip board. One phenomenon that is happening now is that the pulp and paper industries pay similar prices for wood chip as biomass companies, although in the latter case the quality specified for wood chips is less. Moreover, if the prices are equal the pulp and paper industry can have more competition for these resources (Ericsson, 2005). Then, this competition can increase the price of biomass.

Biomass/biofuel market and price

The decrease in real prices of biomass through the learning process and the market is possible. It is the current situation for the Nordic countries, where the price is the key factor regulating the market. This can be a general situation in all Europe, when the supply is increased due to the replication of the pilot projects, which is transferred to the farmer scale. Furthermore, the supply and demand must play their role in the market. Consequently, the production in the large scale could reduce the price and develop the market. It is important, moreover, when the bioethanol prices from Brazil would not keep at 6 US$/barrel for a long time, due to the large demand of it.

Other aspects that have a great influence on biomass/biofuel prices are the investment costs of the equipment or capital costs. The cost is influenced during the depreciation time which is around 25 years. The capital cost is higher for biomass than oil, typically for biomass fuel it is 1300 USD/kWe, while for oil it is 1000 USD/kWe (Azar et al, 2003). For these reasons, support for investment is important. Although, the electricity from hydropower is cheaper; thus biomass is preferred to produce heat and steam, when the industry required it (Alakangas, 2005).

The pattern to use biomass in the region where it is produced has been changing; especially in the northern Europe the use of biomass in the large scale by the district heating and increasing demand of bioethanol have boosted the importation of this. Then, a certification system which guarantees the agreement in whole supply chain is needed, due to the increased production and importation of bioethanol from Brazil and palm oil from India. Also, in the case of automobile fuel, the standard petrol has to be mixed with the ethanol. The current battle is how to standardize this blending. The blend should be 5% of biofuels and 95% of fuel oils and it should avoid any effect in the car use. The current production of biofuel in Europe is not competitive with the bioethanol from Brazil, the EU needs some support mechanisms.

Rising Oil prices

The increased price of oil made favorable biomass, in term of prices. This is one of the most important driving forces, because rising oil prices have increased the demand for pellets, biomass and biofuel production and have expanded the bioenergy sector. It is a driving force, but it is not the only one. In the Figure 3-2 prices for crude oil are shown since 1947 to 2004. The prices in August-2005 are around 60-70 USD$/barrel and the prognosis is that the prices could continue to rise.

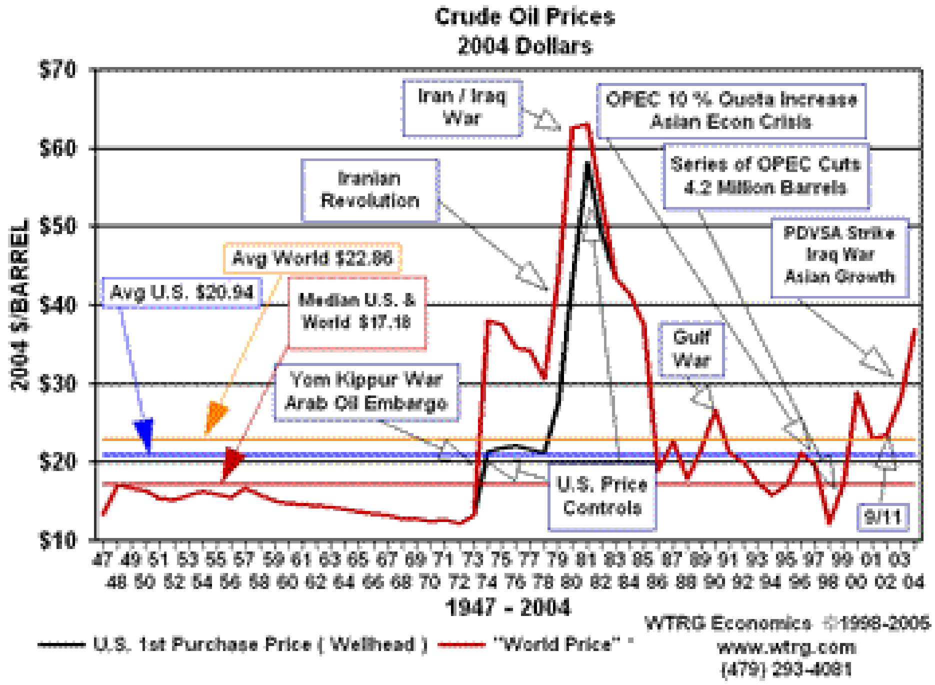

Figure 3-2 Crude oil prices. Source: WTRG Economics. (2005)

The oil price has increased 30% in this year due to: (1) Rising on the demand of industrialized countries and China, who increased the demand in 20% last year. (2) Lower stock, oil companies have tried to become more efficient in recent years and operate with lower stocks of crude oil. (3) OPEC strategic refers to prices modification according with the demand, besides, consumption forecasts by market experts turned out to be too low. (4) Actions of speculators, the combination of low stocks and OPEC action to keep them low leaves the market exposed to the prospect of sudden price rises if supplies are threatened. (5) Violence in the Middle East, the world's major supplier. (6) Other political conflicts, Nigeria and Venezuela have potential to disrupt exports and drive up world prices. (7) There is insufficient

US refinery Capacity. Increased production of new gasoline blends have also helped to drive world crude oil prices, due to that the blend required more capacity in the refinery plants. However, the price was higher in the early 80´s. It should rise to USD$90/barrel to get the same value (BBC News , 2005b).

To achieve the Kyoto emissions targets, EU countries are expected to reduce the use of fossil fuels. Contrary to the prospect that the oil price can decrease, OPEC strategic prices have increased the price of fossil fuel-based energy (i.e. gasoline, natural gas, heating oil and electricity). Azar, in his model, shows that the increases in the reserves do not have significant impacts on the choice of fuel in the transportation sector (Azar et al, 2003). The assumed availability and cost of different primary energy sources are showed in the Table 3-4.

Table 3-4 Assumed availability and cost of different primary energy sources.

Primary Energy Supply	**Cost (USD/GJ)**	**Maximum annual supply (EJ/y)**	**Reserves (EJ)**
Coal	2	----	50 000
Oil	3	----	12 000
Natural gas	2.5	----	10 000
Biomass	3	200	----
Solar hydrogen	18	>1 000	----

Source: Azar et al. (2003).

3.2.4 Climate Change

The projected emission of greenhouse gases (GHG), show that the world's climate could warm by up to 5.8 °C by the end of this century (European Commission, 2005c) . This fact could cause changes on global hydrology and could create effects in the crops physiology and yield.

Global hydrology- Water

There are some changes in the global water due to climate change and competition for water supplies due to the use and abuse of it. These changes are in the surface water, its quantity and quality, in groundwater, its quantity and quality, floods, droughts, and extreme precipitation events and ecosystem vulnerabilities (Pritchard and Amthor, 2005).

Climate change influences the hydrology cycle and regional precipitation patterns and one of the major effects is in the agriculture. Base on historical data, it was estimated that precipitation has already increased 5 to 10 percent during the past century due to more intensive rainfall events and that this contributed to even greater increases in stream-flow during this same period. Rising atmospheric CO_2 and temperature have allowed some researchers to predict a 5 to 10% reduction on the demand by irrigated agriculture by 2030 and 30-40 % by 2090 (US Global Change Research Program, 2004). Other researchers predict that demand for irrigation water will increase because the greater evaporative demand, reduced rainfall and longer cropping season (Rosenwieg, 2004). Although the predictions differ, in general they agree that some agriculture production regions will likely get dryer and some will get wetter.

The ratio between fixed fresh water and population is decreasing, since the population is growing and the per capita water usage is increasing. The highest use of the water withdraw is for irrigation, 69%. Industry is the second use, with 21% and for the third one is domestic use, 10% in 2000. The majority of the water comes from underground aquifers. These reservoirs are renewed slowly by rainwater percolating down through soil and rock. Today, the extraction is bigger than renewal. Other resources are the rivers, lakes and wetland, but these are abused too.

Nearly 4 000 km^3 of fresh water is withdrawn every year, in average 1 700 liters are used per person per day in the world. The average rainfall on land each year is 7 000 liters of fresh water per person, but the water is not uniformly distributed. This means that, 7.8% of the population in 2000 lived with water scarcity less than 1 000 liters per person per day. 24.5 % with water stress (1 000 - 1 699 liters.). 34.7% with insufficient water, (1 700 – 2 999 liters). 16.7% relatively sufficient (3 000 - 9 999 liters), and 16.3% with plenty (more than 10 000 liters).

Table 4-6, shows the water scarcity projected to 2050, the water dependency and the water use for the different sectors in each of the EU-15 countries. Two countries will increase their population by 2050, Ireland and France. The others will reduce it, allowing using more water per person. The average reduction in population around 12% leads to increase the average internal renewable water resource in 6%. The Netherlands and Belgium have scarcity of water now and they remain with the same situation in 2050; but they use 84% and 34% of water from outside the country, respectively. Other countries which have been used higher quantities of water from outside the country are Luxemburg and Germany. On the other hand, the major water use in Europe is for industrial purposes. Only countries like: Greece, Portugal, Spain have the same world pattern about the water use for agriculture. The European average consumption is 19% for domestic consumption, 26% for agriculture consumption and 55% for industry consumption.

Integrated water management is recognized as a key element of dealing with water scarcity. The country index is the sum of five scores out of 20, in which different aspects of water management are: (1) Resource: amount of water available. (2) Access: to an improved water supply and to sanitation. (3) Capacity: GDP per capita, under-five mortality rate, school enrolment rates, degree of economic equality. (4) Use: amount of used per person (50 litres per/day). (5) Environment: water quality and stress, and the importance attached to water and environment (Clarke, R and King J. (2004)). The higher score achieve means better management. The lowest water indexes poverty in EU-15 belongs to Belgium, Denmark and Italy, while the highest are Finland, Austria and Ireland. It is showed in table 3-6 for EU-15. However, it is not the only way to manage the water scarcity. There are two possible more solutions: the desalination and transporting fresh water from wetlands, but it is not the cheapest options.

Table 3-5 Water shortage. Internal renewable water resources per person per year in EU-15.

Country	**Population** (1)		**Internal renewable water resources** (2)				**Water dependency** (3)	**Water use by sector as a % of total use 2000** (4)			**Water Poverty** Index rating out of 100 (2003)
	2000	2050 projected	litres per person per year 2000		litres per person per year 2050 projected		% of water orinating outside country 2000	Domestic (%)	Agriculture (%)	Industry (%)	
Austria	8,1	7,1	6968	▥	8726	▥	29	35	1	64	75
Belgium	10,2	8,9	820	🟥	877	🟥	34	13	1	85	61
Denmark	5,3	4,8	2068	▤	2165	▤	0	32	42	26	61
Finland	5,2	4,9	21269	🟦	23439	🟦	3	14	3	84	78
France	59,2	59,9	2870	▤	2749	▤	12	16	10	74	68
Germany	82,0	73,0	1170	🟧	1356	🟧	31	12	20	68	65
Greece	10,6	8,2	4260	▥	5032	▥	22	16	81	3	66
Ireland	3,8	4,7	12358	🟦	8759	▥	6	23	0	77	73
Italy	57,5	41,2	2771	▤	3710	▤	5	18	45	37	61
Luxemburg	0,4	0,4	2289	▤	1399	🟧	68	13	1	85	--
Netherlands	15,9	14,2	630	🟥	631	🟥	88	6	34	60	69
Portugal	10,0	8,1	3794	▥	4219	▥	45	10	78	12	65
Spain	39,9	30,2	2764	▤	3526	▤	0	13	68	19	64
Sweden	8,8	8,7	19905	🟦	22631	🟦	2	37	9	54	72
Uk	59,4	56,7	2440	▤	2460	▤	1	22	3	75	72
Average EU15	*25,1*	*22,1*	*5758*		*6112*		*23*	*19*	*26*	*55*	*68*

Sources: (1) UN Population Division. (2) (3) (4) FAO Aquastat 2003.

1 m3= 1000 litres		
🟥	< 1000 litres	Water scarcity
🟧	1000 to 1699	water stress
▤	1700 to 2999	Insuficient water
▥	3000 to 9999	Relative sufficient
🟦	>10000	Plentiful supplies

Source: Clarke, R and King J. (2004).

Effects in the crops physiology, yield and forest

Carbon derived from CO_2 in the atmosphere is a key substrate of crop growth. If the CO_2 goes up from 360 p.p.m to 700 p.p.m the photosynthesis rates increase from 20 to 60 % in most species (Pritchard and Amthor, 2005). Elevate atmospheric CO_2 and warming generally enhances photosynthesis in C3 plants and can enhance photosynthesis in C4 plants over the longer term. Then, it improves the growth and yield but will decrease nutrient concentrations within most plant tissues. Global warming increases soil warning. It increases plant nutrient uptake capacity. However, it is uncertain if the capacity to meet extra nutrient demand will arise from greater photosynthetic rates. On the other hand, O_3 pollution will create a nutritional imbalance in crops, because the roots change the assimilation process of the nutrients. While CO_2 increases the productivity (flowers (pollen) and fruit), O_3 can limit the yield; depend on increases in the concentration, timing and duration of O_3.

Lack of fresh water limits crop production more than other resource limitations. Availability of water is crucial because the growth and yield are often linearly dependent to the total amount of the water consumed by the crops during a growing season (Pritchard and Amthor, 2005). The water storage of the soil is getting worse because the irrigation practice is increasing, leading to groundwater depletion and salinitation. Soil salinity problems occur in arid and semiarid agriculture regions due improper irrigation practices (mistimed, too little, too much), poor quality of water and excessive fertilization. Sewage or water waste, used in irrigation, can help to replace the nutrients but not fulfill water needed in energy crops. However, the CO_2 and O_3 rising decrease the quantity of water needed for the crops. If CO_2 concentration increases the amount of water needed to produce a given quantity of plan mass decreases. Besides, the ozone pollution reduces water use by the crops, because it causes stomates to close, reduces plant leaf area, inhibits rooting and lowers root. The reduction is not only in water consumption also in yields. The continuous variation between excess of precipitation and drought has a high priority level to crops breeder, pushing them to create crops resistance to temporary flooding and resistant to drought crops varieties or species.

Most climate change scenarios suggest the favorable climate for boreal forest in the north. It allows the growth of deciduous trees instead of coniferous. The forest productivity will increase around Europe, although it will not be uniform since the northern areas will get higher productivity, in the southern areas it will decrease.

3.2.5 Policies

Policies in bioenergy have stretch relation with other sectors. Although, there are EU policies, their enforcement and implementation depend on the national level. The drivers behind these policies include climate change, energy security, environmental effectiveness, rural development, economic efficiency and market innovation.

Integrated policies

There is a need for an integrated biomass policy which incorporates the agricultural, environmental, rural, forest and transport sectors. Energy crops should be given the same stability as conventional forestry and food crops and not be used as part of set-aside to counter surpluses in food production.

National and local policies and legislation and promotion

In order to achieve the integrated biomass policy is necessary to ensure the implementation of relevant EU directives in all Member States and it to introduce flexibility for Member States to meet EU directives and/or targets on bioheat, bioelectricity and biofuels. For that purpose it is important to harmonize national support schemes for bioelectricity and to harmonize national legislation on biomass, agriculture, forest and waste. Furthermore, the policy makers should receive the information about the result of the successful “real large experimentation” projects, in order to get understanding and competence to develop biomass policies.

Such biomass policies should promote biomass production in the long range. If they are planning to produce energy crops e.g. perennial grass for 20 years, the policies can not be set up for 4 years. Farmers need similar support like traditional agriculture. The Common Agriculture Policy (CAP) support for energy crops should be increased, as well as, the agriculture sector should have enough financial support.

In the forest sector, in the case of Finland, the national forestry policy gives regulations about the conservation of a certain quantity for energy purposes, but in Poland the forest policy is not relate with the energy sector. Each Member State should incorporate a minimum level of requirement for energy purposes (Rogulska, 2005).

On the other hand, support for investments is required, due to the higher cost of equipment. In the case of Finland there is support for heat and steam production. (Alakangas, 2005).

Regarding the biofuel for transportation sector, it should authorize blends up to 15%, revise norms on gasoline according to biofuel blends, set up policies on the control of imports in order to ensure development of the EU liquid biofuel industry, improve infrastructures for biofuels e.g. obligatory filling stations, parking for hybrid vehicles, shift EU structural funds from fossil fuel to bio and continues promotion of biofuels in public transport. This is the case in France, the country with more emphasis in the production of biofuel instead of electricity and heat from biomass; this is a general situation in the southern EU countries.

Policies at the national level are important; if they support the industries then the demand for biofuel could increase. Industry should invest in biomass; in both sides, the production of biomass and the end-use. If the investors perceive coherence in the policies, support schemes, legislation and promotion, they are more likely to invest in biomass. Besides, these polices should take into account the efficiency in the process, cost reduction and performance on different scales.

Other actions that are needed are: to promote further EU-certification for solid/liquid/gaseous biofuels, promote co-utilization of biomass with fossil fuels and reduce time to obtain permits.

Taxes, subsides and other support schemes

Both, the emission trading and green certificates create new challenges and opportunities for biomass. Emission's trading will improve the competitiveness of biomass compared to fossil fuel. Heavy taxation of competing fossil fuels, in order to reduce the health and environmental impact, seems to be the most effective policy instrument in favor of biomass.

Some of the developed countries committed themselves to reduce their collective emissions of six key greenhouse gases by at least 5%. Each country's emissions target must be achieved by the period 2008-2012 (European Commission, 2005c). Each country has to show demonstrable progress towards meeting of its targets by 2005. The three most important gases which must cut are: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_20). Besides, they must be cut the industrial gases such as: hydro fluorocarbons (HFCs), per fluorocarbons (PFCs), and sulphur hexafluoride (SF6). According with the achieved goal, the future actions could reinforce and increase the current goals. EU environmental ministers agreed in December 2004 that keeping greenhouse gases at manageable levels would require a cut in emissions of 25% to 50% by 2050.

If the purpose is to reduce the CO_2 emissions, biomass should substitute for the coal. Coal release 80 Kg of CO_2 per GJ and other fuels release less. Besides, coal has less heat content and need more tones to produce the heat required compare with oil and natural gas. This is showed in Table 3-6.

Table 3-6 Heat content and CO_2 emissions of different energy sources

Fuel	**Heat Content** **GJ/t**	**CO_2 release** **kg/GJ**
Coal	~ 30	~ 80
Oil	42	70
Natural gas	55	50
air-dry wood	~ 15	~ 80*

*If the wood is grown sustainably and combustion is complete, its life cycle CO_2 emission should be close to zero.

Source Boyle G, (2004).

The use of biomass in the transport sector has more impact in the environment than other uses like heat or electricity. In the long term, the transport sector will represent 84% of CO_2 emissions in 2010. The transport sector considers that the use of biomass is a solution in the short and medium term. While the hydrogen and sequestration technologies are developed. It is one of the issues that make attractive the use of biomass for the biofuel production. On the other hand, the Agency on Natural Resources and Energy in Japan reports that they limit the biofuel rate to 3% (E3) because while E3 reduces the emission of CO_2 and carbohydrates compared with gasoline, but the NOx emissions from the fuel production to combustion from E3 are higher (International Energy Agency, 2005). This is part of the LCA measure in the pilot projects.

Nevertheless, Non human caused uncertainties on the global warming arise. According to UK Scientist, if the Siberian bogs melt, there is a big risk their substantial methane load could be dumped into the atmosphere, accelerating global warming. "The 11 000-year-old bogs contain billions of tonnes of methane, most of which has been trapped in permafrost and deeper ice-like structures called clathrates". They said that, the whole western Siberian sub-Arctic region has started to defrost and it "has all happened in the last three or four years" (BBC News, 2005a). The methane has the same effect on the global warming than CO_2 but 20 times stronger per molecule. It could cause an accelerated global warming impact.

On the other hand, the renewable energy resources (RES) promotion measures as part of the prices, gives to biomass a real competition face to the oil products. The current RES promotion schemes in EU are: (1) Green certificates for RES electricity and or emissions, (2) Special tariffs or production support or electricity from RES. (3) Obligatory purchase of electricity from RES, (4) Deregulation of the electricity market, (5) CO_2, NOx and/or sulphur tax, eco-tax, (6)Tax refunding/relief for RES, (7) Investment subsidies, support for RES, (8) Emission limit for boilers, (9) Environment permit system/impact assessment, (10) Support for sustainable forestry, (11) Support for biomass harvesting, (12) Regulation on cultivation of renewable resources, (13) Special regulation for small producers, (14) Guidelines about using natural resources, and (15) Restriction of landfill (Alakangas and Vesterinen, (2003)). All of these are not present in every EU countries and they don't have the same value or support. High tax differences have created tension among the countries, and between different sectors within countries. The higher carbon taxes in Sweden have increased the importation of wood. In order to protect economic competitiveness, the Swedish and Finnish industry paid lower taxes while the District heating paid high opportunity costs.

These promotion measures, standards, regulations and opportunities for development can diminish the influence of the lobby groups. Moreover when there is a lot of support for the oil industry.

3.2.6 Integration

The continuous integration of the supply chain actors could improve the efficiency and competitiveness of biomass. Also, the creation of permanent relations with farmers and industry, through contracts in the long term at certain prices will increase market development. Obtaining research funding from the industry, which can attract more public funding, can help to ensure the commitment of the industry to the large scale development of market competition. More research in the supply chain limbs and support to develop this research can ensure the improvement in the implementation of the different projects, specifically in the productivity and quality required in the conversion process.

The integration should be among the different technologies, as well as, between the different resources to produce the different energy carriers, e.g. biofuel like bioethanol, biodiesel, biogas, biomethanol, biodimethylether, bio-ETBE, bio-MTBE, synthetic biofuels, biohydrogen or pure vegetable oil are produced from different sources and by the different technologies. The multiple combinations of different RES to produce the different energy carriers create systems that should interact with each other in order to get the maximum benefit of all.

4 Assessment of Different Studies

4.1 Results in the Different Studies

There are many different studies about biomass potential. Two approaches are considered: resource-focusing and demand-focusing. The *resource-focusing* studies assess the physical biomass resource that may be available for energy purposes. They describe the inventory of potential biomass sources and assess to the use of the resource for energy purposes. The *demand-focusing* studies analyze the competitiveness of biomass for energy purposes, the penetration in the market and sometimes the quantity required meeting a specific target (Berndes et al, 2003). In this thesis the assessment of five European studies was done: Alakangas and Vesterinen, (2003), Ericsson and Nilsson, (2004), Nikolaou et al., (2003), Siemons et al., (2004), and Karjalainen et al., (2004). They are the most recent studies about biomass potential in Europe. Table 4-1 shows the estimations of the potential of biomass from these studies. Besides, in the case of energy crops it shows land uses and the yield of them. Some of the studies are resource-focusing; some are demand-focusing and others use both approaches

The potential in the different studies are based on different RES, like energy crops, forest residues, crops residues, waste and industrial residues and biogas. The highest potential for energy crops is given by Ericsson and Nilsson, (2004) due to the largest land used compared with others. However, this potential is achieved in the long term, around 2050. The potential for forest residues is much higher in the estimation by Siemons et al, 2004 than is in the estimation by the other authors. Ericsson and Nilsson, (2004) has some scenarios that include high potential of biomass but not as high as Siemons et al, 2004. Forest residues are most important in the short term. Furthermore, the highest potential in the short term is waste and industrial residues as is shown in the studies of Siemons et al., (2004) and Nikolaou et al., (2003).

In *2010,* the biomass potential in the EU-15 studies under analysis is between 3.1-6.2 EJ y-1. To Siemons et al., (2004) the waste residues constitute 30%, forest residues provide 33%. The agricultural residues and energy crops represent 17.5% and 14.3% respectively. The share in Nikolaou et al., (2003) study is similar but the potential from forest residues and agricultural residues is 40% less than Siemons et al., (2004) and the share of energy crops is similar to Siemons et al., (2004) estimation. In the case of Ericsson and Nilsson, (2004) forest residues and energy crops are 50% of the biomass potential, but it is less than the other figures.

For *2020,* the biomass potential in Siemons et al., (2004) and Nikolaou et al., (2003) studies increase by 10-20%. However, the waste residues have the higher share. For Ericsson and Nilsson, (2004) in 2015-2025, energy crops represent 60% in the ecologic and economic scenario of the total biomass potential. Forest residues increase under economic perspective[3] 23%. Then, biomass potential is around 4.8 and 7.1 EJ$y^{-1.}$

For *2050,* Eriksson's study shows that energy crop's potential increases. It varies between 9.1 – 11.7 EJ$y^{-1.}$ The other studies do not consider this time perspective. In the calculation of this potential, the studies´ authors considered different factors that affect the potential, which are discussed later on. However, energy crops represent the highest potential being between 80 – 84%.

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[3] It is apply if the ashes are recycled in other to compensate the loss of nutrients

Karjalainen et al., (2004) study show one of the lowest biomass potential in forest. It is near to 1 EJy-1. The other studies are higher in 30%-70%, and in the case of Siemons et al., (2004) 100%.

Table 4-1 Estimates from the literature of European biomass theoretical and geographical potentials.

Study (perspective time)	**Scope**	**Biogas** (EJ y^{-1})	**Waste/ Ind Residues** (EJ y^{-1})	**Forest Biomass** (EJ y^{-1})	**Crops residues** (EJ y^{-1})	**Energy crops** (EJ y^{-1})	Yield (t ha y^{-1})	Land (Mha y^{-1})	**Total Europe** (EJ y^{-1})
Ericksson	EU15			1,3	0,7	1,1	8,4	7,3	3,1
Scenario 1	ACC10			0,4	0,2	0,4	5,2	4,3	1,0
2015-2025	Bel+Ukr			0,1	0,1	0,3	4,3	3,9	0,5
	EU15			1,3	0,6	2,9	8,7	18,4	4,8
Scenario 2a	ACC10			0,4	0,3	1,4	7,2	10,7	2,1
2015-2025 low	Bel+Ukr			0,1	0,2	1,3	7,5	9,7	1,6
	EU15			1,7	0,6	3,7	11,2	18,4	6,0
Scenario 2b	ACC10			0,5	0,3	1,8	9,3	10,7	2,6
2015-2025 high	Bel+Ukr			0,2	0,2	1,7	9,7	9,7	2,1
	EU15			1,3	0,5	7,3	8,7	47	9,1
Scenario 3a	ACC10			0,4	0,1	3,8	7,0	30,3	4,3
After 2045 low	Bel+Ukr			0,1	0,1	4,3	7,7	30,9	4,5
	EU15			1,7	0,5	9,5	11,2	47	11,7
scenario 3b	ACC10			0,5	0,1	4,9	9,0	30,3	5,5
After 2045 high	Bel+Ukr			0,2	0,1	5,5	9,9	30,9	5,8
Alakangas									
1990	EU15	0,02	0,04	0,49		0,015			0,6
2000	EU15	0,06	0,08	1,42		0,022			1,6
Siemons									
2000	EU15		1,6	1,8	1,0	0,9		set aside (10% agriculture land)	5,4
	ACC10+BG,RO		0,3	0,9	0,3	0,2			1,7
2010	EU15		2,2	2,1	1,1	0,9			6,2
	ACC10+BG,RO		0,4	1,0	0,3	0,2			1,9
2020	EU15		2,7	2,3	1,3	0,9			7,1
	ACC10+BG,RO		0,5	1,1	0,4	0,2			2,2
Nikolaou									
2000	EU15		2,1	1,3	0,6	1,0	10,3	5,6	5,0
	ACC10		0,5	0,3	0,2	0,4	10,3	2,2	1,4
2010	EU15		1,9	1,4	0,6	1,1	10,3	5,6	5,1
	ACC10		0,5	0,3	0,2	0,4	10,3	2,2	1,5
2020	EU15		2,1	1,6	0,7	1,2	10,3	5,6	5,5
	ACC10		0,5	0,4	0,2	0,5	10,3	2,2	1,6
Karjaleinen [(a)]									
2020	EU25			1,0	NC	NC			

Sources: Ericsson and Nilsson (2004), Alakangas and Vesterinen (2003), Nikolaou et al., (2003), Siemons et al., (2004), Karjalainen et al., (2004). (NC Not calculation), (a) technical potential.

Other studies like Hall (1993), Johansson (1993), Yamamoto (2001), Fischer (2001) and Hoogwijk (2004) are mentioned in order to show the different outcomes, but they are not analyzed in detail. They are global studies about biomass and for that reason the European potential is estimated too. The potential varies between 10-26 EJ y^{-1} in 2050 and between 7-21 EJ y^{-1} in 2100. Table 4-2 shows the estimation from the literature of these studies on the global and European biomass theoretical and geographical potential.

Table 4-2 Estimates from the literature of the global and European theoretical and geographical potentials.

Study (perspective time)	Scope	Forest Biomass	Crops residues	Energy crops			Total Europe	Total Global
					Yield	Land		
		(EJ y^{-1})	(EJ y^{-1})	(EJ y^{-1})	(t ha y^{-1})	(Mha y^{-1})	(EJ y^{-1})	
Hall	Eur excl. FSU	2,0	1,3[b]	11,4	15,0	38,0	14,7	31
Johansson (2025)	OECD Europe	1,7	1,4	9	15	30	12,1	62
	FCP	3	1,8	4	10	20	8,76	
(2050)	OECD Europe	1,7	1,4	9	15	30	12,1	78
	FCP	3,1	2,1	12	15	40	17,1	
Fischer (2050)	W Europe	2,3-3,4	2,1[b]	11-14	5,6-7,1	110[a]	16-20	217-245
	CEE	1,2-1,5	0,9[b]	3,9-5,0	10,7-13,8	20[a]	6,0-7,3	
Yamamoto (2050)	W Europe	5-10[c]		16	15	53	21-26	
	F. USSR+CEE	8-20[c]		21	15	70	29-41	
(2100a)	W Europe	7-17[c]		4	15	13	11-21	272
	F. USSR+CEE	11-28[c]		5	15	10,7	16-33	
(2100b)	W Europe	7-17[c]		0		0	7-17	
	F. USSR+CEE	11-28[c]		0		0	11-28	
Hoogwijk (2050) A1 Global- Economic	W Europe	NC	NC	13	3-55,8	NA	13	695
	E Europe			10	3-55,8	NA	10	
(2050) A2 Regional Economic	W Europe	NC	NC	14	3-55,8	NA	14	311
	E Europe			8	3-55,8	NA	8	
(2050) B1 Global-Ecologic	W Europe	NC	NC	10	3-55,8	NA	10	452
	E Europe			8	3-55,8	NA	8	
(2050) B2 Regional-Ecologic	W Europe	NC	NC	16	3-55,8	NA	16	324
	E Europe			9	3-55,8	NA	9	
(2100) A1 Global- Economic	W Europe	NC	NC	21	3-55,8	NA	21	1119
	E Europe			12	3-55,8	NA	12	
(2100) A2 Regional Economic	W Europe	NC	NC	15	3-55,8	NA	15	394
	E Europe			10	3-55,8	NA	10	
(2100) B1 Global-Ecologic	W Europe	NC	NC	15	3-55,8	NA	15	706
	E Europe			10	3-55,8	NA	10	
(2100) B2 Regional-Ecologic	W Europe	NC	NC	18	3-55,8	NA	18	490
	E Europe			11	3-55,8	NA	11	

Source: Yamamoto et al. (2001), Fischer et al. (2001), Ericsson and Nilsson (2004), Hoogwijk et al. (2004).[a] Energy crops from grassland (include permanent pastures, woodland and shrubs). [b] Includes straw and residues from maize and other crops. [c] Includes agricultural residues, such as straw, dung and maize residues, forest residues and industry by products. NC: No calculation, it no is part of the study's scope. NA: No available by region, only global information.

4.2 Key Factors and Sub-factors in the Different Studies

The cross examination of the key factors present in the different studies helps to identify important aspects in the determination of biomass potential. These factors cover the two approaches of resource-focusing studies and demand-focusing studies, while some studies consider both. Resource-focusing study is Ericsson and Nilsson, (2004). Demand-focusing study is: Alakangas and Vesterinen, (2003). And both approaches are: Nikolaou et al., (2003), Siemons et al., (2004) and Karjalainen et al., (2004). Although the studies cover more resources, this analysis is focused on energy crops and forest residues.

4.2.1 Methodology and Assumptions in the Analyzed Studies

Different methodologies were developed by each author. They include different approaches, (supply and demand or both); different biomass potential such us: theoretical, geographical, technical, economic or implementation; different sources of data, statistics or survey; they use assumptions through the time or some projections based on previous real data. Some of them include different perspectives, the economic and ecological. These differences in the methodology are shown in the Table 4-3. Moreover, the following description mentions the most relevant facts in each study.

Table 4-3 Differences in the methodologies of the analyzed studies.

Methodology/Studies		***Alakangas and Vesterinen, (2003)***	***Ericsson and Nilsson, (2004)***	***Nikolaou et al., (2003)***	***Siemons et al., (2004)***	***Karjalainen et al., (2004)***
Approaches	Resource-focusing		x			
	Demand-focusing	x				
	Both			x	x	x
Potential	Theoretical	x	x	x	x	x
	Geographical	x	x	x	x	x
	Technical					x
	Economic	x		x	x	x
	Implementation	x			x	
Data	Surveys	x				
	Statistics		x			x
	Assumptions		x	x	x	
	Projections			x		x
	Model				x	
Perspectives	Economic		x			
	Ecological		x			

Alakangas and Vesterinen, (2003) present a result of the biomass survey in Europe. It covers consumption of renewable energy sources. The included biomass resources are wood fuels, straw and short rotation crops, municipal and industrial waste and biogas. They present the production level in 1990 and 2000. The main provider and user of wood-based energy is the forest industry in countries like Austria, Finland, France, Germany, Italy, Portugal Spain and

Sweden. They present biogas production, where U.K and Germany are the leaders in this sector but there is not a sufficient level of maturity in these potential due to the lack of infrastructure. Furthermore, Ethanol production and Ethyl tertiary butyl ether (ETBE) production are shown for 2000 and 2001. The approach is demand-resources focusing, where the market and prices of biomass play the most important role. On the other hand, the potential showed are the theoretical, geographical, assuming that is necessary to increase the quantity of land to energy production but they do not give any figure about the requirement in land or yield. About the economic potential, the regulated third party could be given positive effect to the functioning of the market. They show how fuel prices vary a lot from country to country, due to the improvement technology and national subsides systems. Besides, in the implementation potential they present the different RES promotion measures in each European country.

Ericsson and Nilsson, (2004) present a biomass potential for energy crops, forest residues and agricultural residues. They use as a forestry and agriculture source UNE/ECE-FAO and FAOSTAT statistics respectively. The national annual feelings for each scenario are assumed constant. The potential harvest of residues varies with the species and age of the tree. The residue from steam wood ratio for spruce is roughly twice of the pine and three times that for birch. Besides the residues steam wood ratio is 50% higher for coniferous trees than deciduous trees. The growing stock for forest is projected to increase by 27% until 2020 compared 1990. The ratios for the ecologic and economic perspective are different. Also by products for forest industry is assume 25%. Ericsson and Nilsson, (2004) assume that energy crop yields are 50% higher than the wheat yield. It is assumed an annual yield increase of 1% year for 30 years. In the Scenario 1, it grows in current set aside land (10% of land arable). In scenarios 2 and 3 is used the 25% of the arable land. And, in scenario 4 and 5 the rest of the agricultural land when is 0.24 ha/capita for food. Besides, the same productivity is assumed in permanent crops, permanent pastures and arable land. They only consider the theoretical and geographical potential of biomass because they use resource-focusing approach.

Nikolaou et al., (2003) carry out the resource the assessment in three steps: (1) The technical resource potential, defined as the total annual production of all resource given no limits. (2) The available resource potential, defined as all resources available with technical, physical, environment, agronomic, silvicultural and economic factors. (3) The energy potential, expressed in gross calorific value. They assumed that energy crops are cultivated in the set aside land. It is 5.6 Mha in 2000 while the arable land was 73.5 Mha. Besides, they assumed a productivity of 10 tonnes per ha. The Forest theoretical potential was calculated for each EU country. Besides, they give the potential biomass for industrial biomass, agricultural biomass and wasted biomass. For the second step, the biomass costs were recorded using cost factors like: production costs, transportation costs and other costs such as storage and handling costs. It was calculated for each EU country for energy crops for solid biofuel, biodiesel and bioethanol production, forest by products and solid industrial residues. For the third step, the potential was calculated with projections according to the growth rate based on previous year information. The set aside land was expected to increase 1% per year. The forest area was expected to expand by 3.3% from 1990 to 2020; and removal was expected to increase 0.7% per year. It means that wood supply for energy purposes will increase 1% per year to 2020. It is used both approaches resource-focusing and demand-focusing. Besides, it considers the theoretical, geographical, economic and in part the implementation potential. The two latter are well developed because the assessment to the future potential is based on market trends and policy developments.

Siemons et al., (2004) use SAFIRE models that simulate the economic investment behavior if there are variations of capital cost, biomass cost and value sustainable premium, (GHG emission trade) are applied. For non tradable biomass type, as wet manure, sewage gas and landfill gas, the balance is done by the operation cost and capital cost. The fuel was taken as zero cost. For tradable fuel, biomass fuel prices are established in the market by the analysis of the supply and demand function. The intersection point of the supply and demand determined the equilibrium prices and quantities. They assumed that the low sustainability premium scenarios are more realistic. However, the model ignores the importation from international sources. Furthermore, they use the current set aside land (10% of arable land). It assumed that 50% of the set aside land is available for solid energy crops and 25% to produce biodiesel and 25% to bioethanol. The sensitivity analysis shows that increasing the sustainable premium boosted the production of biofuel in Germany, France, Spain and UK. But the current arable land is not available to meet the biofuel goals. It considers both approaches resource-focusing and demand-focusing, besides the theoretical and geographical potentials are taken into account. In the technical potential the importance of the efficiency in the technical feasibility and user acceptance is mentioned, but just as a disadvantage. In the economical potential is considered the market and fuel prices and in the implementation potential the importance of the green house gas balance of bioenergy system and different Directives.

Karjalainen et al., (2004) study estimates the energy wood potential in EU25. They did two estimations. First, the round-wood balance where the round-wood is the annual growing minus the felling. It can be used for energy purposes or leave in the forest. Felling residues are 67% from coniferous and 33% from deciduous. And, the second calculation made is the estimation of felling residues from round wood, crown mass and stumps and roots. They calculate the annual increment and the feeling. Besides, 25% of the round-wood balance is used for energy purpose. Thus, the available forest is 984 PJ or approximately 1 EJ, assuming the bulk density 400 kg/m$^{3.}$ The annual incremental data are from the UN-ECE/FAO Forest resource assessment, known as TBFRA-2000. It is a survey of temperate and boreal industrialized countries- The estimation of round-wood and fuel-wood production is based on the data from the Finish statistical yearbook 1999-2001 (Metla 1999-2002). They assumed that the harvest from forest is increase 0.7 % according to ETTS V. Karjalainen et al., (2004) consider technical availability of 75% of clear cuts and 45% of thinning, due to the impact of mountain areas, which has besides impact in the cost. Another assumption is that 20% of the stump wood is harvested. In the third part the estimation of the economic availability is determined by the annual use amount for the plant. Being the long distance the major impacts are in the transportation costs. Another costs considered are the labor, fuel and capital costs. Summarizing the theoretical, geographical, technical and economical potential are considered in for forest residues.

4.2.2 Identification of Key Factors and Sub-factors in the Analyzed Studies

The different studies identify factors in the estimation of the biomass potential. Some of these factors are well developed and explained, while others are just mentioned. In the Table 4-4 the identified key factors in the different studies are shown. In the short term, the overcome of the barriers like market development poorness, scarcity of more sources, more users, and more research program and information dissemination are the most common mentioned.

Alakangas and Vesterinen, (2003) present as the main priority, the harmonization of common energy policy and agriculture policy in order to increase the production of biofuel, as well as, to provide the mechanism to promote the renewable sources, which contributes to environmental protection, sustainable development and recycling carbon by photosynthesis. Other key factors are opening the markets, where the price plays an important role in the competitiveness with other fuels. The pellets market is a one example of that. European statistics on electricity trends in EU from 1996 until 1999 indicate that price of the electricity have fallen by around of 6% on average and by up to 20% in some case.

Table 4-4 Key factors in the analyzed studies.

Factor (2010)	**Sub-factors**	***Alakangas and Vesterinen, (2003)***	***Ericsson and Nilsson, (2004)***	***Nikolaou et al., (2003)***	***Siemons et al., (2004)***	***Karjalainen et al., (2004)***
1. Local capacity	*- Pilot projects,*				x	
	- Information and dissemination				x	
2. Supply chain coordination	*Promotion*					
	= Biomass sources		x			x
	= Customers to electrical and thermal energy and biofuel.					x
	= Acquire technology from abroad.					
	= Market development	x		x		
Factor (2050)	Sub-factors					
1. Land uses	*Population growth and consumptions patterns*		x	x		x
2. Efficiency	*Yield/water*		x			
	Harvest rate			x		x
	Conversion technology			x	x	
	End-use					
3. Price competitiveness	*Resource competition*		x			x
	Biomass/biofuel market and prices	x			x	x
	Rising oil prices					
4. Climate change	*Global hydrology- Water.*		x			
	Effects in the crops physiology and yield and forest.		x			x
5. Policies	*Integrated policies,*	x	x		x	
	National and local policies, legislation and promotion	x				x
	Taxes, subsides and other support scheme	x			x	x
6. Integration						

Ericsson and Nilsson, (2004) identify the largest potential for energy crops, for that reason, land uses and CAP policies are the key factors. The yield and management practices should include the ecological impact. Another factor is climate change, which influence the crops, yield and forest. The second largest potential is the forest, which is influenced by land uses as preservation areas and low and high harvest ratio. The low ratio based upon ecological considerations, which prevent the depletion of forest land. The alternative uses of the forest industry residues generate resource competition for energy purposes. Moreover, the water is mention as a factor that influences the yield. Climate change is mentioned as factor that influences the yields and water availability.

Nikolaou et al., (2003) carry out the potential with projection according to the growth rate based on previous year's information. Energy crops are growth in the set aside land and rising 1% year by year due to a increment in the relative profitability of arable crops. The forest increase 1% by year due to expansion in the forest area. Other factors are the cost, (production, transportation, storage and handling) that could be associated to the efficiency of the yield and conversion technology.

Siemons et al., (2004), in the demand approach identifies as a key factor, the role of the environmental protection into the market through the tax exemption associated to the renewable energy and trade of GHG emissions. It is boosted by goals in electricity, heat, transportation and industrial sectors. In the supply approach identifies the fuel as tradable and not tradable. The key factor is the market, the role between the demand and supply in the determination of the price and quantity. Also, the size of the sustainable premium, GHG emission trade, is essential for biomass role. The efficiency of conversion technology is important in the reduction of emissions in the production for energy purposes, and in the reduction of the capital cost, which affect the competitiveness of biomass as a fuel. On the other hand, they say there is need to harmonize the sustainable premium in the RES Electricity Directive and Transport Directive, because they are clearly of different order to magnitude. Besides, continues development in pilot projects and in the dissemination of the information is needed too.

For *Karjalainen et al., (2004),* new legislation and promotion on renewable energy are important elements to meet the Kyoto protocol requirement. Development of forest resources depend on the change in the policy to the market framework. Besides, it depends on various factors: climate change, land use history, afforestation of former agricultural land, increased nitrogen deposition, temperature and CO_2 concentration. Due to the demand for natural protection, the competition of the wood resources is increasing. The use of round-wood directly depends on the prices, especially for wood based panels, pulp and paper and energy production. In the estimation of economic availability, the cost is the important consideration, i.e. labor, fuel and capital cost. The transportation cost could increase the value if the distances are big enough, as well as, the productivity in the machine, which are involved.

5 Analysis

The study of biomass potential is a complex issue, due to its multivariable nature and the difficultly of specifying all the involved variables, as well as, their interactions. Taking into consideration different approaches, different time perspectives, different methodologies, different assumptions, and different national goals contributes to a better understanding of the key factors that influence biomass potentials.

All studies identify the most important resources for biomass potential in the short term: forest residues and industrial, agricultural residues and waste. However, in the long term the contribution of energy crops is higher in the majority of the cases. In general, if the time perspective is longer the biomass potential increases.

The factors considered in the resource-focusing approach are related to the availability of the sources. However, the demand-focusing approach gives more attention to competitiveness and penetration in the market. In the case of Ericsson and Nilsson, (2004), who use the resource-focusing approach, fewer factors are considered than other studies, which have the demand-focusing approach or both of them.

It is difficult to say if the different studies have considered the theoretical, geographical, technical, economic and implementation potential completely. All of them took into consideration the theoretical and geographical potential, but in the other it is not clear. In the technical potential, they mention the importance of the efficiency in the technology but are not clear if they consider the losses due to the conversion process from primary sources to secondary energy carriers. In the economic potential, they consider cost supply curves, but it is not clear what costs they took in consideration. It is the same for the implementation potential, authors who considered the institutional constrains and incentives, do not give clear descriptions and the impact of each measure. In general they consider some aspects of the different potentials but not all of them.

Some studies have a short time perspective and they consider fewer assumptions. Others prefer to use real data and projections. Nikolaou et al., (2003) and Siemons et al., (2004) have a time perspective up to 2020. They consider a conservative projection, for example the set aside land for energy crops is kept at the current 10% of the arable land. While in Eriksson's study, whose time perspective scope is around 2045, the growth of energy crops is 25% of the arable land and in the last scenario, the rest agricultural land when is 0.24 ha/capita for food. Furthermore, while Ericsson and Nilsson, (2004) assumed that energy crops yield are 50% higher than the wheat yield. Nikolaou et al., (2003) assumed the productivity per hectare is 10 tonnes, which is really low compared with the productivity of the perennial grasses, i.e. Miscanthus achieve a yield of 42-49 t $ha^{-1}y^{-1}$ (odt), when nutrients and water are not limited (irrigation). On the other hand, Nikolaou et al., (2003) expected to increase the set aside land 1% per year, due to previous years information, while Ericsson and Nilsson, (2004) assumed increment due to the CAP. The most significant assumption is about the agricultural land used for energy crops and their yield. Furthermore, Siemons et al., (2004) assumed 50% of the set aside land to produce solid energy crops and 25% to produce biodiesel and 25% bioethanol. It is the only study which divides the different energy purposes and the different sources for biofuel to transport.

In the case of the forest the assumptions are less. For forest residues the methodology is also different. While Karjalainen et al., (2004) present the most detailed methodology, Nikolaou et al., (2003) give a general analysis based on expected increase in forest area and in the removal rate. At the same time, Siemons et al., (2004) give a projected supply and demand curve of biofuel for electricity and heat generation for 2010. While Karjalainen et al., (2004) carried out the annual availability and the fuel cost in the plant. The difference is that Karjalainen et al., (2004) consider the supply cost according to the distance to plants. Neither of them considers the biofuel for transportation. There are agreements in the growth rate of forests, and in the share of energy purposes of 25% from the forest industry by-products, but not in the rate of the removal of residues. These aspects imply different assumptions. For example Karjalainen et al., (2004) consider the technical potential which reduces the theoretical potential of the clear cuts, thinning and stump wood.

Naturally, there are uncertainties around biomass potential. One of the most important factors is climate change. It affects the yield in energy crops, the growth rate of the forest and the water availability significantly. How much it will change and how it will affect biomass potentials, is a "wild" guess, although there are some estimations around its effects but never about how fast it will be change.

On the other hand, biomass sector is broad and any expert has a limited competence, e.g. biofuel for transport instead of electrical and thermal energy purposes, or forest instead of energy crops. For that reason opinions are influenced by knowledge, competences, and national goals. The North countries traditionally use biomass to produce heat and electricity in cogeneration, and the South countries prefer to use biomass to produce biofuels.

5.1 Short Term 2010

Key factors in the short term are present now and their outcome will be vital for the set up of biomass policies and the exploitation biomass potential not only in the short term but also in the long term.

For every expert the most important factor in the short term is the development of pilot projects. It leads to know-how and local capacity in a successful biomass project. If the project brings gains to all stakeholders and actors, they will continue to support the development. This aspect is shown in the survey carried out by Alakangas and Vesterinen, (2003) where the local potential of biomass around Europe is lower in comparison with the outcomes of other studies. This means that the estimation is more optimistic than the real local use of biomass.

These projects can overcome the lack of understanding of the use of biomass for energy purposes by decision makers at different levels, lack of understanding of the biomass benefit by the decision makers and public in general, lack of understanding of bioenergy technologies, and lack of understanding of environmental impacts.

The dissemination of the outcome of these projects is a significant factor. Visiting the different projects could give a near experience and credibility of the result, in order to reply these projects in other areas. An information center with easy access to everybody offers confidence to the public in general about the benefits of biomass. The use of communication methods is important for spreading suitable knowledge.

These projects must develop the supply chain coordination. It is important especially in the short term. Other aspects like the scale will be important in the long term. All actors are important, nobody is more important than others. If one of the actors is absent, it is not possible to achieve the planed outcome. The chain is formed by the development of the supply and the demand, the acquisition of the technology, and the market growth. This chain starts with resources, for that reason the most important factor in the long term is boosting the access to resources.

The analyzed studies in general do not take into account the key factors in the short term or they are mixed with the long term key factors. Nikolaou et al., (2003), Siemons et al, (2004) and Karjalainen et al., (2004) consider stable condition and linear growth of the factors during the perspective time study, which is from 2000 to 2020. This is show in the analysis of the factor in the long term.

5.2 Long Term 2050

The real information from pilot projects provides enough confidence about biomass. And the predecessors' actions should enhance the potential of it.

The key factors have a relation with the resource-focusing and the demand-focusing approach. The resource-focusing approach has a relation with land uses and yield efficiency. If there is more land and higher yield, it means that there is more potential. Both factors contribute to increase the inventory of biomass. The other factors have more relation with the demand resource approach. The user efficiency is related with the demand. The efficiency is considered in the technology aspects too, in the conversion of the primary source into the energy carriers. The efficiency is related with the competitiveness. Still, it is not the only factor that affects the price competitiveness, because this factor has more sub-factors. If there is resource competition, the prices will be increased. However, learning processes can reduce the costs. Besides, biomass supply from abroad helps to regulate the price in the biomass market. Although these facts give a lot of competitiveness to face with the rising oil price, the most effective measure is taxation of fossil fuels and the opportunity to take advantage of emissions trading and green certificates.

Policies affect both approaches. The integration of agriculture and energy policies gives the opportunity to increase the available land for the growth of energy crops. The integration of forest policies with energy policies could increase biomass resources too. Furthermore, the integration with other policies like the transport sector can boost the market. But the national policies play a very important role. They can encourage, in the long term, supplier and consumer to increase the market

Climate change more than other factors is an uncertainty. It influences the key factors associated with the resource-focusing approach. If the concentration of CO_2 increases the yields will raise too. Besides, it can have effects on the crops physiology. However it is not the unique change, the water will be affected. If there is scarcity of water for the irrigation, the costs will be higher. Then, the cost for the crops could be higher too. If considering only rainfall, the periods of drought and flooding can affect the selection of crops and their productivity. Otherwise, the policies around environment protection should be stricter.

Engaging industry for the large scale development of market competition is a necessity for the growth of biomass potential. However, the industry needs to feel confidence, in order to be involved more and support further projects. For that reason, the continued integration of different actors helps to increase the inventory and market growth. At the same time, the use of industrial investment in research programs can keep alive the future advances of biomass.

On the other hand, the environmental impact of energy crops depends on the selection of crops and management practices. The yield efficiency includes the assessment of life cycle assessment (LCA) and environmental impact assessment (EIA). Pilot projects aim to develop knowledge to get a balance between the productivity and the ecological protection. For that reason, water is not a specific factor; it is part of the yield sustainable efficiency. The harvest rate of forests should have the same trend, in order to get a sustainable perspective.

Integration as a factor is not identified in the different studies but some authors mention the necessity to improve continuously. Ericsson and Nilsson, (2004) suggest improvements in the yield by 1%. This increment can be gradual or it can be stipulated by policies. However, the gradual increments might not generate enough confidence in the farmers, producer, and end-user. Long, stable and integrated policies give more stability for investors and actors around the biomass industry. The integration between different RES and technology to use in the different energy carriers is not well development in the studies as a key factor.

All factors are interrelated; their development depends on their relations. Policies affect land uses, and the price competitiveness. It defines the land availability for energy crops and forest reservation, as well as, how to use the land to produce biomass or biofuels and the quantity of forest residues available for energy purposes. Besides, the environmental policies can affect the taxation on fossil fuels and boots biomass potential, affecting the price competitiveness. Furthermore, the efficiency in the yield, technology and end-use affect directly the competitiveness of biomass. Moreover, the yield and the crops physiology are affected by climate change. This means that biomass potential is a system, then, one factor affects progressively the others, how is shown in the figure 5-1.

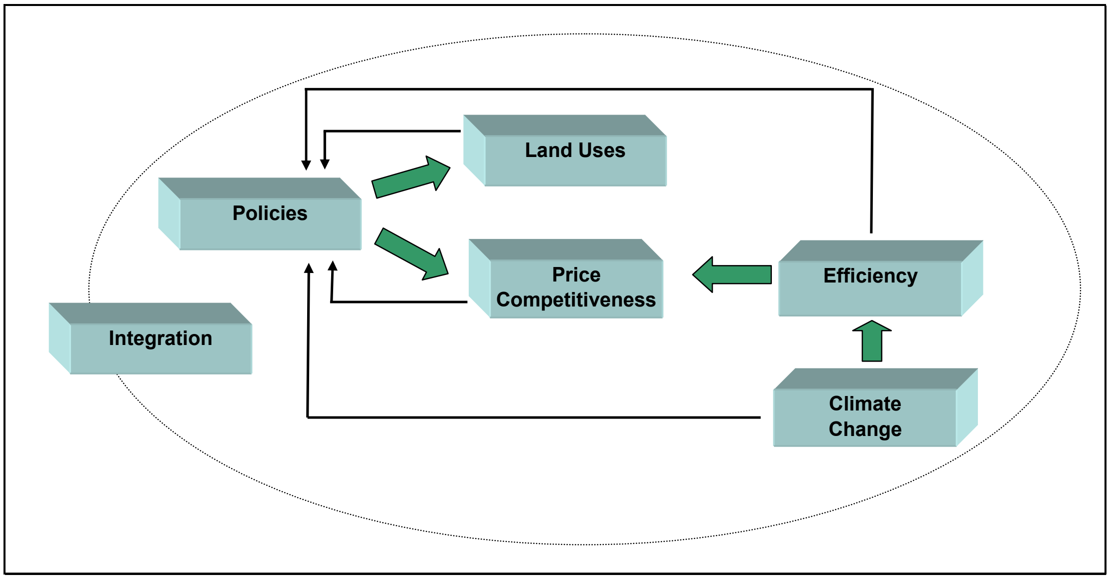

Figure 5-1 Interrelations of the key factors in the long term. The thick arrows indicate the main influence between the different factors. The think line is the feedback into the different factors.

Furthermore, these factors must feedback into the policies overtime. If the efficiency is increasing, the environmental mechanisms that support biomass can be changed gradually. Moreover, if climate change is disrupted excessively, the policies can change too.

Using a criterion of the significance, the factor that causes the majority of the effects is policies. It is definitively the most important factor in the potential of biomass. It has a direct influence on land uses and price competitiveness. Furthermore, policies receive feedback from other factors in order to respond to change in the system. However, the factor which shows the outcome of all relations is the price competitiveness. It receives the influence of the policies factor and the efficiency factor.

On the other hand, studies as Nikolaou et al., (2003), Siemons et al, (2004) do not make any difference between the key factors in short and in long term, for energy crops and forest residues; as well as, Karjalainen et al., (2004) for forest residues. Nikolaou et al., (2003) consider that agricultural land use for food decrease by 1% year. Then, the seat aside can grow the same percentage (1%). Siemons et al., (2004) consider the same biomass potential for energy crops and biofuel during the whole period, from 2000 to 2020. For the forest, Nikolaou et al, (2003) and Siemons et al., (2004) argue a steady wood energy supply and use to grow around 1% a year from 1990 to 2020. Karjalainen et al., show different net annual increment a lot among country group. Nordics, Central-Eastern and Central-Western Europe represent 78%. Baltics, North-West Europe, Iberia and South & South Western Europe comprise 22%. But also, in general forest residues are expected to rise 1% by year to 2020. The other factors which are taken into account in the different studies do not vary in the time perspective. These are related with the market and price of biomass and biofuel. For Siemons et al, (2004), Karjalainen et al., (2004) and Alakangas et al, (2003) the role of the environmental protection into the market through the taxes exemption is important, due to their influence in the price. The integration between different policies is important to achieve the biomass/biofuel goals. For Nikolaou et al., (2003) the efficiency in yield and conversion technology influences the costs. In general, some factors have interrelation with others, but not in all studies show the same interrelations or the same factors.

Ericsson and Nilsson, (2004) is the study with the longest time perspective. Arable land for energy crop increases from 10% to 25% and in the last scenario agricultural land is above that which is assumed to be required for food production (0.24 ha/cap). Yield increase 1% by year. Regarding forests two scenarios is estimated. They do not depend on the time perspective. They are related with high or low harvest ratio. The other factors as climate change, policies, land uses and resource competition influence the land availability and yield. This study considers different scenarios and the interrelation with the other factors are explained.

6 Conclusions

The key factors that affect the biomass potential for energy purposes in the EU-15 can be identified both in the short term and in the long term. All of them are interrelated as a component of a system. The outcome of one of them, can affect the others. The outcome to the key factors in the short term will affect the key factors in the long term too.

The most significant sources for biomass potential in the short time are forests residues and in the second place industrial and agricultural residues, and biological and domestic wastes. Moreover, in the long term the highest contribution is from energy crops followed by forest residues. The current pilot projects have an emphasis on production of energy crops, because it can increase their share in the biomass potential in the future. The factors that affect their potential in the short and long term are similar for both resources. These key factors have been strongly supported by interviews with researchers in the field of bioenergy.

In the short term, the *local capacity* through the development of the successful projects and dissemination of their results is the first key factor. Furthermore, the second factor is the *coordination of the supply chain* in those projects. Both factors are the starting point to enhance the biomass potential and to overcome the current barriers surrounding biomass utilization.

In the long term, the key factors identified are: (1) Land availability, (2) Efficiency in the yield, in the conversion technology and in the end-use, (3) Price competitiveness, (4) Climate change, (5) Policies and (6) Integration. All key factors are interrelated and their outcomes influence the others, the factor with major relevance is policies. It is not only because it affects other factors, such as: land uses and price competitiveness, but also, it receives feedback from other factors, such as: the effectiveness and climate change. Moreover, climate change affects the effectiveness and this affects the price competitiveness. Subsequently, the factor that shows the outcome of all interrelations between the different factors is the price competitiveness. This means that price competitiveness is the consequence factor, while the policies factor is the root cause of the biomass potential. If the policies are modified the effect is bigger compared to the modification of any other factor.

Behind each factor there are some sub-factors that are related directly to it. The first key factor, *land availability* for energy crops and forest is affected by population growth and consumption patterns of food and fiber, as well as, the areas for reservation and forest exploitation.

The second factor is the *efficiency* in the yield, in the conversion technology and in the end-use. The balance between ecological and economic perspective plays an important role in energy crops cultivation. The harvest rate from the forests is important in the ecological perspective. Water is considered part of the efficiency. Irrigation of the plantation can be done by water and rainfed. Furthermore, the efficiency in the end-use means the acceptation of the user and the guarantee of permanent demand. The efficiency in the whole chain, including the conversion technology gives competitive advantage that is reflected in the price in the secondary energy carriers.

The third factor is the *price competitiveness*. It depends on the resource competition in the case of forests. Besides, other factors included are: the rising oil prices, the biomass market price, international biofuel trade. These are influenced by the investment costs and the necessity to standardize the biomass and biofuel resources.

The fourth factor is *climate change*; it affects the crop's physiology and yield, as well as, the hydrology cycle and regional precipitation patterns. It can generate periods of floods and droughts, affecting the water availability and also, the agriculture. Climate change can influence the policies around environmental protection; if it changes speedily, the policies could turn more in favor of biomass.

Furthermore, the fifth factor is *policies*. The integration of biomass policy with the agricultural, environmental, rural development, forest, industry, trade and transport sectors has a significant importance in the potential of biomass. The most relevant point is the coherence between the local policies, legislation and promotion programs. Besides, taxes, subsides and other support schemes affect the competitiveness, e.g. emission trading and green certificates.

The sixth factor is *integration*. The continuous improvement through the pilot and R&D projects and the participation of industry as an investor leads to growth in the market and increase the share of biomass in the market. The use of different RES and different technologies for the production of different energy carriers needs constant integration.

The diverse outcomes of the European studies reflect the variety of methodologies, approaches, perspectives, potentials, and key factors that were taken into consideration in the estimation of the biomass potential. The survey done by Alakangas and Vesterinen, (2003) identified the local use, being 3 times less than Siemons et al., (2004), who estimated the potential for the same year. Also, the variation in the outcomes by the different studies is between 3.1 to 6.2 EJ y^{-1} for 2010, and between 4.8 to 7.1 EJy^{-1} for 2020 and the highest potential is presented by Ericsson and Nilsson, which is around 11.7 EJ y^{-1} around 2050.

The differences in the studies are many. The most important factor diversifying the result is the time frame that is influenced by the land availability for energy crops and yield. It is the case of the Ericsson and Nilsson, (2004) study, which has the time perspective around 2050. They present the largest potential due to the fact that they consider more land availability for energy crops and more yields. Another factor is the resources taken into the consideration. Siemons et al., (2004) and Nikolaou et al (2003) take more resource than others, e.g. the classification of the different resource cover waste, industrial and agricultural residues, organic waste, sewage and landfill gas. These studies have the highest potential in waste and agricultural residues due to the great details and categories of resources taken into the consideration. Alakangas and Vesterinen, (2003) consider only forest residues and they show the lowest biomass potential.

On the other hand, these studies take into consideration some factors but not all of them. They do no take into account some interrelations between them. Some mix the barriers with the factors. Besides, they do not consider the current transition period of the set aside land. More of them have a short perspective time. Only one study has a long time perspective the long term and presents different scenarios in the estimation of the biomass potential.

Biomass can play a large role in the future energy systems. Taking into consideration these key factors can help planners to estimate the potential of biomass for EU-15 using different scenarios. And, at the same time, to achieve the energy policy goals of secure energy supplies, low health environmental impact, rural development and economic competitiveness through higher efficiency use and lower cost supply.

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Abbreviations

ACC10	Bulgaria, the Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia, Estonia, Latvia and Lithuania.
Bel-Lux	Belgium and Luxemburg
BG	Bulgaria
CAP	Common Agriculture Policy
CDM	Clean development mechanism
CEE	Central Eastern Europe (Bulgaria, the Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia).
CHP	Combined heat and power
d.b.	Dry basis
EJ	Exa-joule (1018 J)
EREC	European Renewable Energy Council
ETBE	Ethyl tertiary butyl ether
EU15	Austria, Bel-Lux, Denmark, Finland, France, Germany, Greece, Ireland, Italy, The Netherlands, Portugal, Spain, Sweden, the UK. West Europe.
FUS	Former Soviet Union: The Baltic country (Estonia, Latvia and Lithuania), Belarus and the Ukraine.
GHG	Green House Emissions
GJ	Giga-joule (109 J)
ha	Hectare
IEA	International Energy Agency
kWel	Kilowatt electrical
kWh	Kilo watt hour
kWth	Kilowatt thermal
m	meter
MJ	Mega-joule (103 J)
MSW	municipal solid waste
MW	Megawatt
MWh	Mega watt hour
odt	Oven dry tone
p.p.m.	Particles per million
RO	Rumania
SRC	Short rotation crops or copices
toe	Tone oil equivalent
w.b.	Wet basis
y	Year

Conversion Factors

toe	11.63 MWh = 41 868 GJ
Mtoe	41 PJ
1 tonne	Mg= 1000 g
1 km2	100 hectares
1 litre	1 m3

Appendix 1. Interviews

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Appendix 2. Questionnaire

The methodology is going through the different questions according to the previous answer. The interview has three sections.

1. The principal question
2. Specific questions
3. Summarizing the ideas in the short term and long term.

1. The principal question is the following:

What are the key factors in the potential of biomass?

2. Specific questions.

These others questions are carrying out the interview, but some of them depend of the previous answer. In your opinion:

About the integration and infrastructure

How is the bio-energy business integrated with the feedstock production and with the consumer?

How is the integration regarding with the assessment, knowledge and infrastructure?

How is the integration between the different actors? (Farmers, buyers, researching organizations, policy makers)

About the scale effects, learning and research and development.

Are there scales of economics regarding production?

….regarding research and development?.

… regarding learning by doing by the market participant?

Is the investment cost and maintenance cost considered so higher?

About the market

Is the market for biomass developed?

Are there any imperfections in the market?

Are there other regulations that influence competition in the bio-energy industry?

Competition with other business

Are competitions with the oil natural gas in the selling market?

What are the possibilities for biomass sector to compete in technology?

Are other competitions? For example, in raw material, land.

Policy influence

Are there lobbying strength of competing industries?

Lobbying strength of biomass organization

What are the policy risks? (Probability that the policy change)

What is the legitimacy of the policy? (Is the policy the sum of pressure group lobbying or a way to provide common goals?

Acceptance and opinions

Are local people knowledgeable about bio-energy?

Are local policy markers knowledgeable about bio-energy?

Can bio-energy create business or local development?

About Socioeconomic and institutional barriers

Are there capacities to evaluate biomass projects?

Are there successful planning around the biomass projects?

Is there good communication around biomass issues?

3. Summarizing

Which of these factors are in the short term and which of them in the long term?

Do you consider that factors as land availability, water, biomass price, oil price, policies and local policies, etc., are key factors?