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RENEW

Renewable fuels for advanced powertrains

Integrated Project

Sustainable energy systems

Scientific report
WP5.1 Biomass resources assessment

Period covered from: to: Date of preparation

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1 Introduction

The biomass resources assessment was performed within the European project Renewable Fuels for Advanced Powertrains (RENEW), which is supported by the European Commission within the 6th Framework Programme.

RENEW project investigates different production routes for so called biomass-to-liquid (BtL) automotive fuels made from biomass. Biomass resources availability assessment is an objective of work package WP5.1 “Biomass resources and potentials” lead by EC BREC from Poland. The aim of the assessment was to investigate the available biomass resources in order to select the most promising regions for BtL fuel production in Europe.

The biomass assessment was focused on lingo-cellulose biomass as a suitable raw material for the BtL plant and comprised three categories of biomass resources: (i) agriculture crop residue, (ii) energy crops and (iii) forestry biomass. The assessment was conducted respecting the assumption that food and fibre production shall not be affected.

The biomass potential estimation incorporates RENEWS scenarios defined in cooperation with other work packages. The frame conditions of the scenarios can be characterized as following:

- **Starting Point** (SP): reflects the current situation and estimates the average biomass potential for the years 2000-2004.

- **Scenario 2020**: is the projected situation for the year 2020 when the BtL industrial production plants will be under operation in Europe. In order to achieve this projection the average biomass potential of the year 2020 must be estimated. Two variations are included: (i) **Scenario S1**, which represents intensive biomass production based on high level of inputs, and (ii) **Scenario S2**, which represents a biomass production with minimal required level of inputs.

This report is a result of a common effort of a group of RENEW partners: EC BREC, CRES, IEE, ESU-Services, Lund University and UCD.

2 Methods, data and assumptions

2.1 General approach

The biomass potential assessment in Europe was assessed using a resource-focusing approach. Biomass categories included in the study are: forestry residues, wood industry by-products, crop residues and energy crops. In quantifying the estimated biomass potential, units of primary energy were used (PJ/year and GH/ha, year-1).

The biomass assessments were performed on the national level and regional level (NUTS-2 or NUTS-1, *Nomenclature of Units for Territorial Statistics*). The scope of assessment was EU25, excluding Malta and Cyprus (insignificant biomass potential), plus Romania, Bulgaria and Switzerland. All the countries were grouped into five European regions, see table Table 2.1. Project representatives of each of the regions were responsible for delivering regional specific data for the potential assessment.

Table 2.1 European regions and project partner's responsibility in the biomass potential assessment

European region	Countries	Project partner responsible
NORTH		Lund University
WEST		IEE
EAST		EC BREC
SOUTH		CRES
ALPINE		ESU Services
UK and IR		Dublin University

The assessments were carried out for starting point and two future scenarios defined in cooperation with other RENEW work packages. Concerning the biomass potential assessment each scenario describes the potential for development of biomass production within a given time frame, dependent on a number of factors. Table 2.2 outlines the scenarios' criteria and important assumptions for the investigated biomass categories. The assumptions are presented in more detail in section 2.2 – 2.4.

Table 2.2 RENEW scenario assumptions regarding different biomass categories

	Starting Point	Scenario S1	Scenario S2
Time frame	2000-2004	2020	2020
		Food and fibre production must not be affected.	
General description	Current frame conditions for biomass production. Average production/harvesting technology of today.	Maximal available biomass production. Maximal yield from land unit.	Biomass production with minimal negative impact. Sustainability aspects emphasized.
Forestry residues and wood industry by-products	Availability of forest residues based on current forestry management conditions. Timber supply for wood industry not affected.	Increased rate of wood final felling and more intensive biomass removal from forests. Timber supply for wood industry not affected.	Reduced intensity of forest exploitation and lower rate of residue removal. Timber supply for wood industry not affected.
Crop residues	Availability of crop residues based on current crop production and residues redistribution, e.g. animal bedding, itp.	Estimation of future crop production. Higher rate of crop residue removal from the field. Less straw needed for animals rising.	Estimation of future crop production. Lower rate of residues removal from the field. More straw is used for animal rising (less intensive animal production system).

Energy crops	Current lingo-cellulose energy crops cultivation area in Europe plus production potential based on total fallow land. Energy crop yields of today.	Energy crops cultivation on surplus land in Europe after supplying food demand. Intensive crop production based on high level of inputs.	Energy crops cultivation on surplus land in Europe after supplying food demand. Crop production with minimal required level of inputs.

For the future scenarios projections on population by United Nations were used. For agriculture biomass assessment (crop residues and energy crops) projections on future consumption were used in order to estimating required food supply in 2020. Prospects on agriculture crop yields and production were derived from official European Union documents on agriculture sector. The details are presented in section 2.3 – 2.4.

For consistency in assessments international statistics were used. Forestry data were taken from the Temperate and Boreal Forest Resource Assessment 2000 (UN/ECE-FAO, 2001, TB FRA 2005, FORESTAT). Agricultural data were collected from the EUROSTAT. Moreover, the project partners responsible for the European regions delivered a set of regional specific factors in order to perform the biomass potential assessment. Finally, the regional partners were responsible of verifying the results of assessment taking into consideration the specific conditions of biomass production in each of the European regions.

2.2 Forestry residues and wood industry by-products

The assessments of the potential supply of forestry residues and wood industry by-products were based on forest biomass growth rather and current national felling rates. Based on the (theoretical potential) total amount of residues and by-products that can be produced in forestry and wood industry sector, respectively, the technical potential was estimated as the biomass amounts available after supplying the forest environmental requirements and competitive uses in wood industry.

The biomass potential from forestry is composed of four fractions:

- logging residues,
- thinning wood,
- root biomass,
- wood balance.

The potential of biomass from wood industry is grouped in four fractions:

- by-products from sawmills,
- by-products from pulp and paper industry,
- by-products from board industry,
- by-products from other wood processing industries.

The method of theoretical potential assessment is based on specific factors, which allow conversion of input data from the international database into amounts available for BtL uses. The estimation was based on the areas covered by forest available for wood supply, net annual increment and felling rates specific for each European country (TB FRA, 2000; TB FRA, 2005). The values of regional specific factors, which were not possible to derive from the database, were taken from literature or relevant experts. If it was not possible to define the factors on the national level the average value for Europe was used.

In order to assess the technical potential available for BtL the theoretical potential was reduced. Ecological restrictions are necessary for proper and sustainable functioning of forest ecosystem. Various difficulties make it technically or economically impossible to harvest and suply the residues (small, scattered felling areas, slopes, etc.). Finally, part of the harvestable residues is utilized by wood industry, like fibre board industry, and must be excluded from the total available potential for BtL if the rule that food and fibre production cannot be affected is applied.

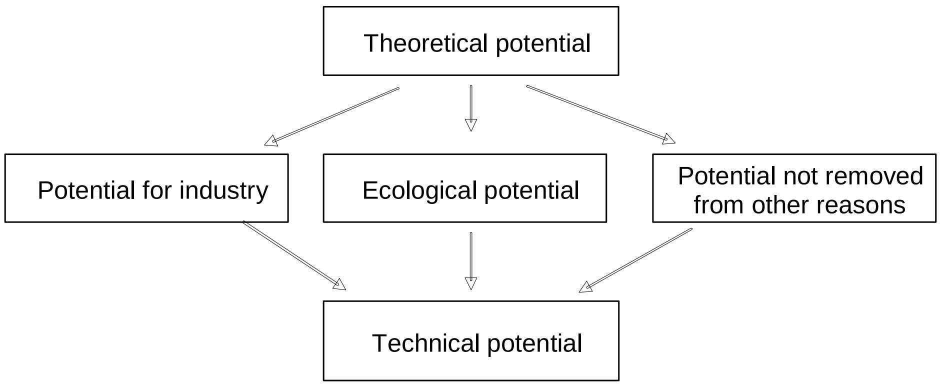

Figure 1. *Scheme of the method for technical potential calculation*

Logging residue

Logging residue is defined as woody biomass, which is produced during harvest of merchantable timber (i.e. contains trees tops and branches including leaves and needles). The calculations of theoretical potential were based on the annual felling overbark of forest available for wood supply. A value of factor of logging residue was applied. The potential for coniferous and broadleaves species was calculated separately as there are important differences between the amount of residues produced by coniferous and broadleaves trees (Jyvaskyla, 2000; Kubiak, 1994). Moreover, there is a very different value of the factor for pine and spruce dominated coniferous forests. This is due to the difference in a structure of pine tree and spruce - the amount and thickness of branches. According to these differences, logging residue factor has three different values, respectively for broadleaves, for pine and for spruce.

In the future scenarios the value of factor of final felling is modified according to the assumptions of future scenarios. The value of change in felling was estimated based on projections of the European Forest Sector Outlook study and experts opinions (European Forest Sector Outlook study, Main Report, Geneva, 2005).

Technical potential is calculated by reduction of theoretical potential by three factors described previously: ecological potential, potential not removed from other reasons (Jyvaskyla, 2000; Hakkila 2004; Rzadkowski, 2000) and potential for industry.

Thinning wood

The thinning cuttings include late cleaning (pre-commercial thinning), early and late thinning (commercial thinning).

The division for wood harvested during thinnings and wood removed during final fellings does not exist in databases used for calculations. According to this fact this values are estimated indirectly as the value of fellings overbark on forests available for wood supply considering thinning fellings and factor of final fellings (Rozanski, 2003; Wojcik, 2003). The value of fellings overbark on forests available for wood supply for S1 and S2 scenarios is estimated on the base of value of felling from SP corrected by factor of felling changes (European Forest Sector Outlook study, Main Report, Geneva, 2005).

The theoretical potential calculated this way is reduced to technical potential by two factors: potential for industry and potential not removed from other reasons (Hakkila 2004; Laurow, 1994). Ecological potential is not taken into account because the thinning cuttings have not interfered strongly in the cycle of chemical elements in forest ecosystem (Rzadkowski, 2000; Kubiak, 1994; Rozanski, 2003).

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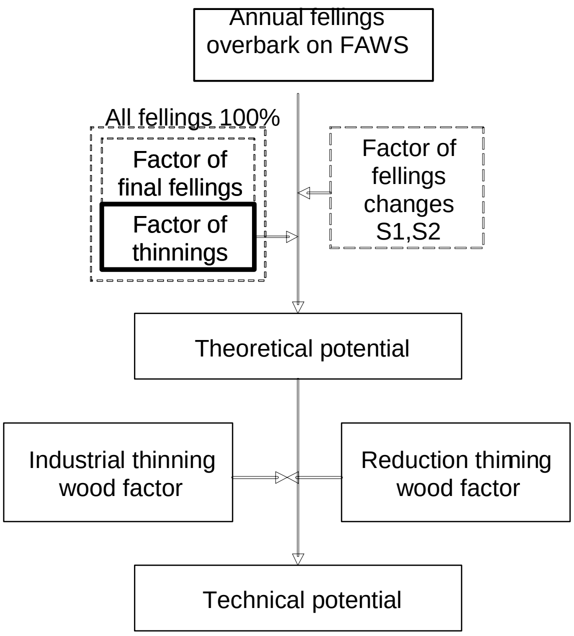

Root biomass fraction (RB)

Root biomass is defined as underground mass of wood e.g. stump and roots excluding small roots. There is an assumption made, that root biomass is extracted only after clear final felling in coniferous forest – spruce and pine. Extraction of root biomass on areas exploited by other type of cutting is excluded because of ecological reasons (Laurow, 1994; Kubiak, 1994). Among coniferous species, from which the most popular are pine and spruce, root systems are easier to be extracted therefore these species are taken into account in methodology (Hakkila 2004).
The base for the estimation of theoretical root biomass potential is the share of clear final fellings in spruce and pine forest stands. This value is calculated as the multiplication of fellings overbark on forests available for wood supply by factor of clear final felling and factor of share of spruce and pine in all species. Then the result is reduced by root biomass ratio – percent of root biomass in all steam (Hakkila 2004; Kubiak, 1994).
The technical potential is estimated by reduction of theoretical potential by: potential for industry, ecological potential, potential not removed from other reasons (Hakkila 2004; Wojcik, 2003). For West Europe region, United Kingdom, Ireland and Poland the ecological potential is assumed to be 100 % for all scenarios, because the ecological restrictions do not allow extraction of root and stumps.

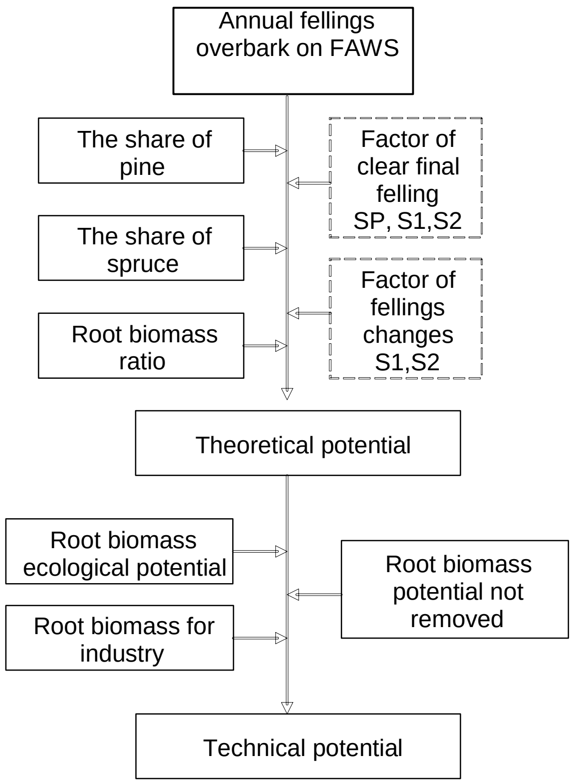

Figure 2. *Scheme of root biomass assessment*

Wood balance fraction (WB)

Wood balance is estimated as the difference between Net Annual Increment and fellings of growing stock. Because of the fact that Net Annual Increment is defined as average annual volume of increment in analyzed period of time excluding the increment of trees which have been felled or died, in the total amount of fellings only fellings of alive trees must be taken into consideration. That is why the fellings of growing stock are included in the calculations. The value of Net Annual Increment and fellings of growing stock for future scenarios have been corrected by two factors: changes of net annual increment and factor of felling changes (European Forest Sector Outlook study, Main Report, Geneva, 2005; TB FRA, 2000; TB FRA, 2005).
Technical potential is calculated according to the same rules as for other fractions, by reduction of theoretical potential by factors: potential for industry, ecological potential, potential not removed from other reasons (Kubiak, 1994; Hakkila 2004; TB FRA, 2000.

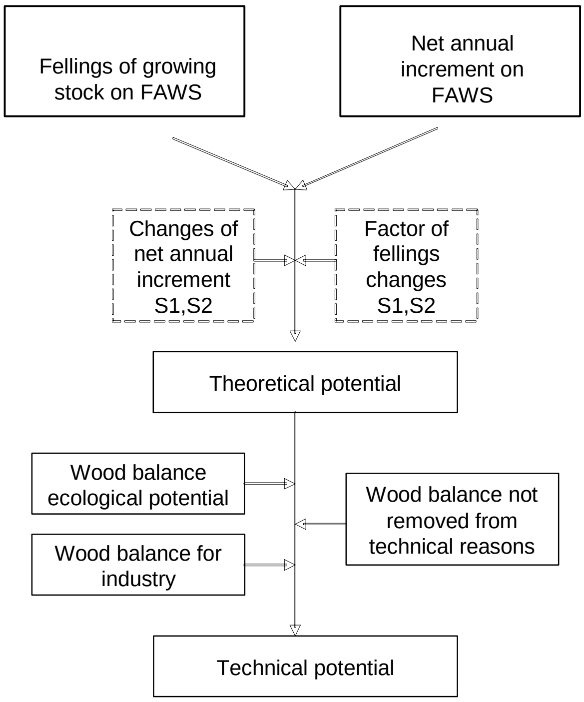

Figure 3. *Scheme of wood balance potential assessment*

Wood industry by-products

The share of different types of wood utilization varies among wood industry branches. Due to this fact the estimation is done for each wood industry branch separately. The sort of wood used for production, factors of by-products production and utilisation are assessed on the base of information from industry plants, literature and expert opinions. The current utilisation of wood industry by-products for energy is excluded from the total potential available for BtL. The reason is that by-products are very commonly utilised for own energy purposes of the wood industry factory and it is important factor for the its competitiveness.

Following values are received as the percentage of by-products from wood used as the raw material (100%) (Jyvaskyla, 2000; Laurow, 1994):

- 40% for sawmills,
- 30 % for pulp and paper industry,
- 20 % for board industry,
- 30% for other industries.

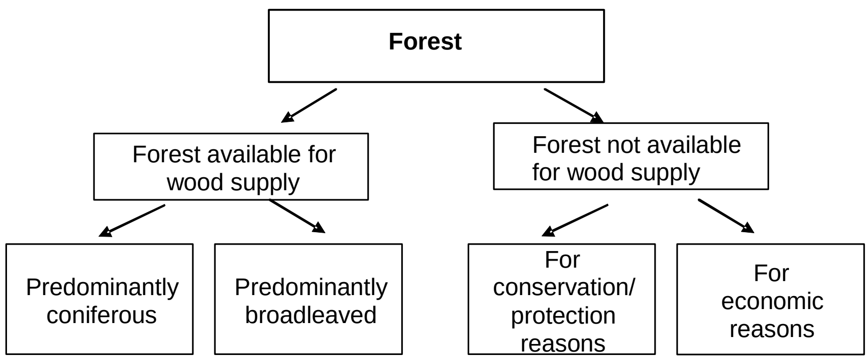

Figure 4. *Scheme of forest area availability*

2.3 Agriculture crop residues

The aim of the methodology is to estimate the surplus of agricultural residues, which is not utilized and could be available for BtL production. There is a strong assumption that food (also fodder) and fiber requirements must be fulfilled first. Only the surplus can be used for other purposes such as BtL. It should be stressed that in the methodology the current and future straw utilization for heat and electricity production is not taken into account. It is assumed that these straw resources could be available for BtL, which is the matter of market competition.

The potential of agricultural residues is estimated for:

- cereal straw (small-grain cereals: wheat, barley, rye),
- oilseeds straw (rape seed, sunflower, soya),
- maize straw (only for maize for grain).

The interdependencies between NUTS regions are not taken into account in the methodology.

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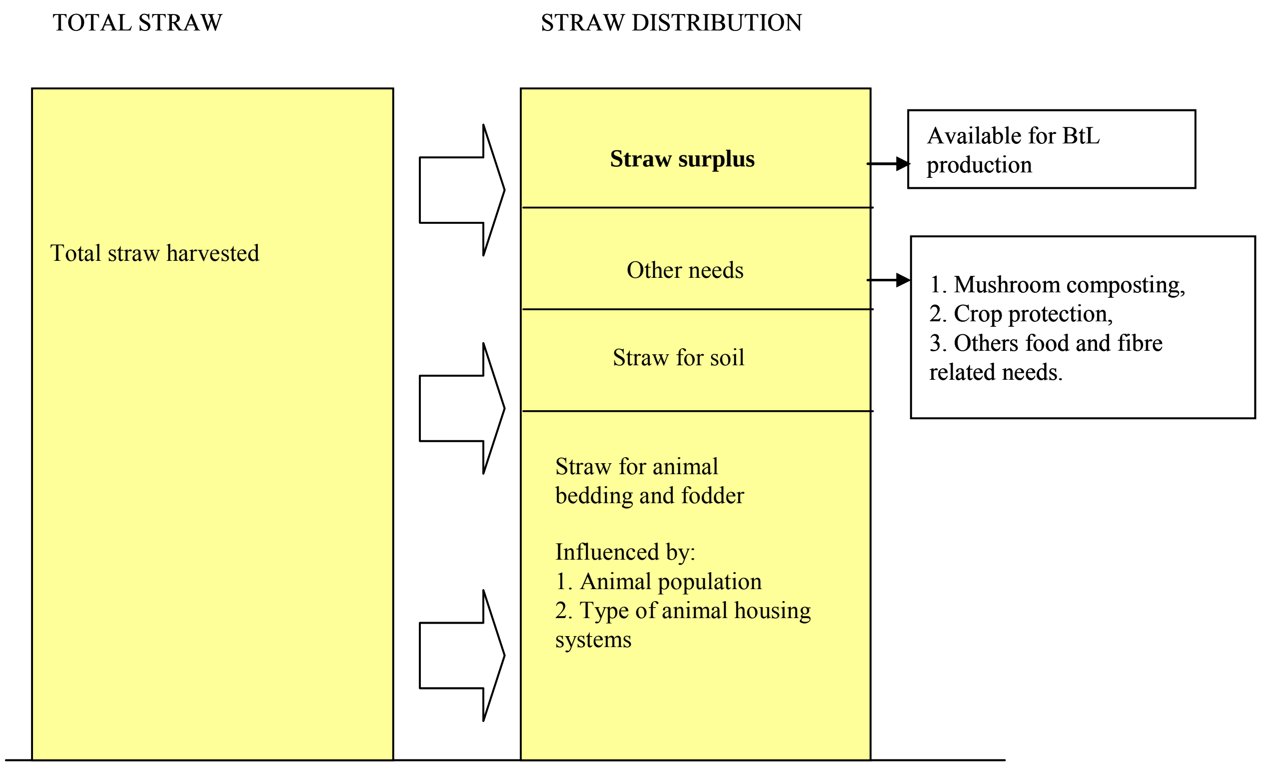


The methodology to assess the amount of straw residues in the NUTS-2 regions consists of the several steps. For the exact equations see Annex 3.

Total straw production

Total straw production is based on total cereal production (average from 2000-2004) and a straw/grain mass ratio. The ratio refers the amount of crop residue, which could be technically harvested. For each type of residues (cereal straw, oilseed and maize residues) the mass ratio of the most common crop of a given group is taken for the calculations, e.g. for cereal straw the straw/grain ratio of winter wheat is applied, as this is the most common crop among the small-grain cereals in Europe. For oilseed residues the ratio of rape is applied.

Straw for animals

The straw requirements for animals are estimated for cereal straw only. Oilseed and maize residues usage for animal production (bedding or fodder) is insignificant. Cattle, pigs, sheep and equidae (horses) are animals, which traditionally need straw for breeding. Cattle and equidae need straw also as a bulky fodder.

In the methodology straw requirements (bedding and fodder) are calculated for cattle, pigs and equidae based on the number of livestock units (LU) and straw demand in tons/LU/year. Specifically, the requirements of straw for bedding depends on the type of animal housing system; systems with straw bedding and without bedding are common in Europe. For each country the share of animals kept in housing systems with straw bedding is estimated (based on Burton C. and Turner C. 2003).

For S1 and S2 scenarios the calculations are based on current livestock units (2000-2004), however the parameters of population change and meat consumption in 2020 are applied as they will influence the animal population. The factors of straw requirements for bedding and fodder as well as the share of animals kept on straw have been estimated for 2020.

Straw amounts needed for sheep and poultry bedding are far less than for cattle, pigs and equidae. Sheep most of the year are kept on grazing. For this reason there is only a rough estimation of these amounts (instead of exact calculation). For simplicity reasons these straw amounts are included in the category “Straw for other purposes” in the result sheets.

Straw for soil

Part of the straw should be left in the field as to ensure high content of organic matter in the soil and thereby long-term productivity of the soil (Börjesson and Gustavsson 1996). In the methodology the requirement of straw for soil is calculated for all types of straw: cereal, oilseed and maize. It is assumed that 30% of the total straw produced must be ploughed back into the soil. This is based on the recommendations of good agricultural practices (Smagacz 2003).

Straw for other purposes

Straw is also used for gardening (like crop protection), mushroom compost, as a building material and other needs. Straw use for these purposes is considered only for cereal straw. It is important that current energy production from straw is excluded from the calculations.

Straw surplus - available potential

Total available straw potential (surplus), which could be used for BtL or other needs is calculated as a distinction between total straw production and the requirements for animals, soil and other purposes. The available straw potential shows the amounts of surplus straw while food and fibre production is not be affected (for all scenarios). However, in real cases the potential available for a certain solution will be changeable due to price competitiveness of different straw uses. This is not included in the methodology.

Sensitivity analysis

The straw potential model allows analysing sensitivity of straw potential on different parameters for respective scenarios and regions.
The scope of parameter variations can be modified, however model allows definition four variables in one step. The starting variables are: – 20%; -10%; 0%; 10%; 20% and they are changeable.
The parameters which are considered:

- demography change
- Consumption change rate,
- cereal straw/grain ratio SP-S2
- straw for animals (bedding and fodder)
- share of straw for soil
- share of straw for other purposes.

2.4 Energy crops

The Land Allocation model was built in order to estimate land area available for energy crops (measured in 1000 ha) and to calculate the energy crop production potential based on the land and energy crop yields. The model operates on statistical data derived from agricultural statistics and various input parameters. The LA model print screen is presented in Annex A.
Structure of the model
Land allocation should be understood as agricultural land allocation (in hectares) for specific crops production (in tonnes).
The model includes five components, which are strongly linked to each other:

- Module for land allocation for agricultural crops in the current situation (2000-2004).
- Module for the estimation of future crop production and yields.
- Module for land allocation for agricultural crops for the future scenario (2020).
- Module for land balancing (surplus land or lnd deficits).
- Module for the energy crop potential assessment.

The overall model structure is presented in **Fehler! Verweisquelle konnte nicht gefunden werden.**. Mathematic equations used in the model are presented in Annex D.
Module for land allocation for agricultural crops in the current situation: This module performs land allocation for arable crops on the basis of statistics on production amounts (1000 t) and yields (t/ha) available for NUTS-2 regions. To avoid annual yield fluctuations the mean values of 2000-2004 are used. The cultivation areas of crops are received in hectares. Additionally, the areas of fallow land, permanent crops and grasslands are applied into the model.
As an outcome land use structure is estimated for the present situation (2000-2004) for each NUTS-2 region. This is balanced with the statistical data on land use to avoid significant discrepancies. Land allocation for 2000-2004 represent a baseline for future land allocation in the year 2020. In the module, the crops are grouped into several categories based on EUROSTAT classification, see 0.

Land use structure and crop groups according to EUROSTAT classification

Utilized Agricultural Area			
Arable land	Permanent	Permanent	Other

Cereals	Oilseeds	Industrial crops	Root crops	Fodder and grazing from arable land	Pulse	Fallow land	crops	grassland	
Wheat, barley, rye, oats, maize grain, etc.	Rape seed, sunflower, Soya bean	Cotton, flax, tobacco, etc.	Potatoes, sugar beets, etc.	Maize fodder, etc.					

Module for the estimation of future crop production and yields: Land allocation for 2020 is preceded by estimations of future yields and future crop production amounts.

To estimate future yields, the NUTS-2 regions were classified as extensive or intensive based on the agricultural production systems. This is based on input consumption, see section 1.1 and Annex B. Depending on the classification on the type of the agricultural system; the module applies different yield increase rates for the future scenario.

In this module the future food/fodder/fibre crop production is estimated based on the population and 'per capita' food consumption forecasts introduced into the module as input parameters, see section 1.1.

Module for land allocation for agricultural crops for the future scenario: Land allocation for 2020 is performed for the estimated future food/fodder/fibre crop production areas and future yields, which are the outcomes of the above described module. During the allocation procedure for 2020 the cultivation area for some crops may exceed the area in the present situation (due to higher consumption rates). To avoid overlapping of crop areas or exceeding the total agricultural some rules are incorporated into the model:

- Compensating land deficits within the same crop category – if the cultivation area of a crop in 2020 is exceeding area of 2000-2004, the land deficit is compensated with land released from other crops within the same crop category (crop categories see 0).
- Setting to zero for a crop category - if deficit for a whole crop category occurs (area of 2020 exceeds the area from 2000-2020), they are not compensated by land released from another crop groups or from permanent grassland; no land for energy crops is available from this specific category.
- Setting to zero for whole arable land – if the arable land under crops estimated for 2020 (sum of cultivation areas required in 2020) is to exceed the arable land of 2000-2004 (including effect of the rules above), no arable land is released for energy crops.

Module for land balancing: The land areas available for energy crops in 2020 are estimated based on change in the land allocation between present conditions and the year 2020. The following land categories are dedicated for energy crops:

- Land released due to the crop productivity increase (relevant for food/fodder/fibre crops).
- Fallow land.
- Land released due to reduction of a certain part of cereal and meat export surplus. Relevant only for net exporters of cereals or/and meat.

If the effect of yield increase is higher than the effect of consumption increase (typical for most of the regions in Europe), some land is released from the cultivation area of particular crops. This is the surplus land that may become available for energy crops. The procedure is presented in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Module for the energy crop potential assessment: Energy crop production potential in PJ is calculated as the available land (in 1000 ha) multiplied by energy crop yield (t/ha dry mass) and a relevant low heating value (GJ/t). The LA model gives the opportunity to match the different types of available land with different energy crop yields based on soil quality classes. The following rules are accepted:

- For land areas released from arable crops, energy crop yields relevant for average soil quality are applied.
- On the fallow land and land released from permanent crops, energy crop yields relevant for poor quality soils are applied.

The energy crop production potential estimated for each NUTS-2 region is aggregated into country levels.

Model's simplifications

A model is a simplification of reality, and as such, certain details are excluded from it. The question is always what to include and what to exclude. The LA model was built to aid the development of future patterns of crop production on agricultural land in the sense of assessing the crop cultivation areas and production potential. The intention was to include only the most relevant components so that the model would not be too complicated and would support the understanding of future allocation of crop production.

Simplification used in the model will result in uncertainties discussed in sections 4.1 and **Fehler! Verweisquelle konnte nicht gefunden werden.**. Following simplifications were used:

- The same yield growth rates (the yield growth rates of cereals) were applied for all crops.
- The national export/import balances were applied to all NUTS-2 regions of a given country at the same level.
- The consumption change rate defined for a country level was applied at the same value to all NUTS-2 regions.
- The cereals exports assumed to consist only of wheat (wheat yields were used to estimate the land area released from cereal exports).
- Land released from beef exports related only to permanent grassland (no change in arable crops).
- Using the same consumption change rate for all crops.
- The interactions between regions (trade) are not considered.

1.1. Assumptions on future scenarios

Two scenarios for the year 2020 were included:

- Scenario S1 represents intensive biomass production based on high level of inputs; food and fibre production should not be affected.
- Scenario S2 represents biomass production with minimal required level of inputs (fertilizers, pesticides, etc.); food and fibre production should not be affected.

While defining the detailed assumptions on the scenarios for energy crops potential assessment various parameters' values were changed in the LA model. The change in the parameters directly affects the result of the model. Following parameters can be changed:

- Consumption change rates.
- Yield increase rates.
- Fallow land conversion rate for energy crop land.
- Permanent grassland conversion rate for energy crop land.
- Export surplus conversion rate for energy crop land.

The 0 shows the summary of assumptions for scenarios S1 and S2. The justification of these is given below the table.

Parameters into the LA model to determine the land availability for energy crops for scenarios S1 and S2

Parameter	Scenario S1	Scenario S2
Consumption change rates	-1.89 – 15.63%	-1.89 – 15.63%
Yield increase rates	10% for intensive system, 30% for extensive system	7% for intensive system, 20% for extensive system
Fallow land conversion rate	100%	100%
Export surplus conversion rate	30%	No conversion
Permanent grassland conversion rate	1-10% depending on the beef export amount	No conversion

<u>Consumption change rate</u>

In order to estimate the demand for land area and the agriculture crop production for the year 2020, the population and 'per capita' food consumption forecasts are used. The forecasted rate of change in population for 2020 and aggregated 'per capita' consumptions (shown in grain equivalents (GE)) are derived from Thran et al. 2005, and are represented in 0. The population projections come from German Federal Statistical Office, the EC and the UNO.

The same consumption change rate is applied for scenarios S1 and S2.

Changes in population, 'per capita' consumptions and total food consumption in grain equivalents (GE) in % for European countries (Thran et al. 2005)

Country	Population Change		Change in consumption per capita		Food consumption change*
Year	2000-2010	2010-2020	2000-2010	2010-2020	2000-2020
Austria	1,47	1,17	4,80	0,00	7,58
Belgium/Luxembourg	2,75	2,22	1,40	0,00	6,50
Bulgaria	-6,89	-7,88	6,90	7,00	-1,89
Switzerland	n.d.	n.d.	n.d.	n.d.	7.58**
Czech Republic	-1,06	-2,22	3,20	5,50	5,33
Denmark	3,28	2,49	6,00	0,00	12,20
Estonia	-4,24	-2,83	5,40	5,00	2,98
Finland	1,8	1,1	3,30	0,00	6,32
France	3,17	1,1	3,20	0,00	7,64
Germany	1,07	-0,29	2,10	0,00	2,89
Greece	1,5	-0,65	7,10	0,00	8,00
Hungary	-2,97	-3,34	7,30	5,30	5,97
Ireland	8,63	4,36	2,00	0,00	15,63
Italy	1,53	-0,75	4,40	0,00	5,20
Latvia	-5,27	-5,29	5,70	5,70	0,24
Lithuania	-4,06	-4,29	8,10	5,00	4,23
Poland	-0,75	-1,69	6,60	5,40	9,63

Country	Population Change		Change in consumption per capita		Food consumption change*
Year	2000-2010	2010-2020	2000-2010	2010-2020	2000-2020
Portugal	1,09	2,1	8,00	0,00	11,47
Romania	-3,75	-4,19	6,90	7,00	5,48
Slovakia	0	-0,93	-	5,60	4,62
Slovenia	-0,41	-2,14	6,50	3,90	7,84
Spain	0,17	-1,18	5,50	0,00	4,43
Sweden	3,63	3,51	5,70	0,00	13,38
The Netherlands	6,3	3,72	-1,50	0,00	8,60
United Kingdom	3,56	3,49	7,00	0,00	14,68

* aggregated by EC BREC

** the figures for Switzerland were assumed to be at the same level as for Austria (EC BREC)

n.d. – no data

The consumption change rates were used to calculate the future food production. Next, they were used together with the import/export balances for the estimation of the future production volumes of food and fodder crops in a given region.

The current trends in agriculture export/import are assumed to continue until 2020. Cereal and meat exports are estimated not to increase significantly in the next 10-15 years. The justification for this is based on agricultural prospects in the EU and expected reduction in the export support (DG Agriculture, 2006). The direction of 'export/import flows' are not analyzed within this study. Self-sufficiency of the countries and regions (all required crops produced domestically) is not considered to be a realistic assumption. Thus, imports are expected to be sustained in the future and change with the food consumption rates.

Yield increase rate

The increase in yields would show a differentiated pattern among various regions in Europe. The current agricultural production system would determine greatly the future crop yields. To follow this assumption all regions (NUTS-2) are divided into two groups of agricultural production systems: extensive or intensive. The division is based on inputs consumption: (i) fertilizers, (ii) pesticides and (iii) fuel use. The data are derived from FADN and EUROSTAT databases. If the level of inputs consumption is below the one calculated as average for Europe, the agricultural system was classified as extensive, otherwise it was assumed to be intensive, see Annex C.

In Scenario S1 in regions of extensive production it is assumed that the yield growth is expected to reach 30% by 2020 (1.1% per year), whereas the intensive production regions should exhibit a lower growth of some 10% (0.5% per year). In Scenario S2 the yield growth rate is reduced with 30% compared to S1, which results in 20% increase rate for expensive production regions and 7% for intensive production regions, respectively.

As a reference for the estimation of the yield increase rate in S1, the DG Agriculture prospects on agricultural markets in Europe were used (DG Agriculture, 2006). In this document it is stated that yield growth in the EU15 countries (intensive production) slowed down considerably over the last decade and this would suggest that production is at the technological frontier even in the most competitive regions. Therefore, future annual gains in yield appear limited (0.5% per year). In the EU12 countries (extensive production) yield growth had picked up shortly before and after EU accession, though at significantly lower rates than projected (on account of the slower than expected structural change). Therefore, the further yield growth is assumed to be of 1.1% per year.

Energy crop yields

To harmonize the assessment with other RENEW work packages, i.e. WP5.3 'Economic assessment', the energy crop yields have been derived from deliverable D5.03.04 "Energy crop production costs in the EU". These are yields typical for large-scale commercial plantations and are defined for several crops in three land quality classes, see 0.

Perennial energy crops yields for large-scale plantations for Starting Point and Scenario 2020 for three classes of soil quality (D5.03.04)

	Yield level for 2005			Yield level for 2020		
	Average soils	Poor soils	Good soils	Average soils	Poor soils	Good soils
			North			
Willow	9,0	7,5	11,0	12,6	10,5	15,4
Poplar	9,0	7,5	11,0	11,3	9,4	13,8
RCG*	7,5	6,0	10,0	10,5	8,4	14,0
Triticale**	11,0	9,0	14,0	11,6	9,5	14,7
			East			
Willow	9,0	7,0	12,5	12,6	9,8	17,5
Poplar	9,0	7,0	12,5	11,2	8,8	15,6
Miscanthus	11,0	9,0	17,0	17,6	14,4	27,2
Triticale**	9,0	7,0	12,0	9,5	7,4	12,6
			UK & IE			
Willow	13,0	11,0	14,0	18,2	15,4	19,6
Poplar	13,0	11,0	14,0	16,2	13,8	17,5
Miscanthus	18,0	15,0	19,5	28,8	24,0	31,2
Triticale**	18,0	13,0	18,0	16,8	13,6	18,9
			West			
Willow	10,0	10,0	12,0	14,0	14,0	16,8
Poplar	10,0	10,0	15,0	12,5	12,5	18,8
Miscanthus	16,0	8,0	25,0	25,6	12,8	40,0
Triticale**	12,0	10,0	15,0	12,6	10,5	15,8
			Alpine			
Willow	10,0	8,0	12,0	14,0	11,2	16,8
Poplar	10,0	8,0	13,0	12,5	10,0	16,2
Miscanthus	11,0	8,0	16,0	17,6	12,8	25,6
Triticale**	11,0	9,0	14,0	11,6	9,5	14,7
			South			
Eucalyptus	12,0	10,0	14,0	15,0	12,5	17,5
Switch grass	13,0	11,0	15,0	18,2	15,4	21,0
Triticale**	8,0	6,0	10,0	8,4	6,3	10,5

* reed canary grass

** whole crop (grain and straw)

For scenario S1 the yields estimated for the year 2020, represented in the 0 were use. In scenario S2 the respective yields were reduced with 30% to reflect less intense cultivation (lower level of fertilization), see D5.03.04.

<u>Fallow land conversion rate</u>

In the land use structure of 2020, the area of fallow land is kept at the same level as in 2000-2004. By definition, fallow land is land included in the crop rotation system, which is left to recover normally for the duration of a crop year (CODED, 2007). Fallow land can be used for energy crop production, but not for the harvesting of food crops. Fallow land may be (i) bare land bearing no crops at all, (ii) land with spontaneous natural growth, which may be used as feed or ploughed in, (iii) land sown exclusively for the production of green manure (green fallow).

Current fallow land is a consequence of set-aside obligation plus voluntary fallow land. It is assumed that in the mid-term (10-15 years) the Common Agriculture Policy regulations to prevent food (grain) overproduction in Europe will be maintained, i.e. the set-aside obligation will be continued. This would mean that food or fodder crops will not be allowed to expand on the fallow land area. This would only be possible for non-food crops, such as energy crops. Thus, 100% fallow land is assumed as available for energy crops in both scenarios, S1 and S2.

<u>Export surplus conversion rate</u>

It is assumed that some land may be released from cereal and meat export surpluses in the scenario S1. For scenario S2 no land release from exports is investigated.

Cereal and meat exports are only considered as other agricultural products for export are far less significant in the land use structure. For the countries that are net exporters of cereal it is assumed that the area equivalent of 30% of the cereal export could be released for energy crops in 2020. The future yield level is used to recalculate the weight amounts (in 1000 tonnes of grain) into land area. The share of 30% export surplus converted into land for energy crops is chosen as maximum acceptable level. This is due to the position of agricultural export in the structure of Gross National Product in some countries. Moreover, exports are vital for countries due to the available exports subsidies. Bigger changes on the export markets would significantly affect the food market in Europe.

Additionally, pork exporting countries may release some land from the production of coarse grain. The maximum level of 30% of export surplus of pork would release land for energy crops. The tonnes of pork meat expressed in grain equivalents (1 t = 3.75 kg of GE) are used to estimate the released land area from cereals (Niewiadomski et al., 1992).

Permanent grassland conversion rate

In scenario S1 a conversion of permanent grassland into bioenergy plantation was included. This is only relevant for the beef exporting countries. The conversion rate is estimated at maximum at 10% of permanent grassland, due to the risk of depletion of soil carbon stocks. Conversion of pasture to bioenergy plantations may lead to losses or gains in soil C, depending on the relative balance of organic inputs and decomposition rate under the old and new land uses (IEA Bioenergy, 2006). On pastures where soil C is initially high the equilibrium soil C stock under bioenergy systems may be lower than the stock of the previous pasture. Due to this effect the conversion rate of 10% at maximum is used in the calculations. The assumption is confirmed by the level of changes in the area of permanent grassland observed in the statistics of different countries during the previous 15 years (EUROSTAT).

2.5 Energy crop suitability

The target of the energy crop suitability analysis is the evaluation of geographically assigned agro-climate conditions for selected energy crops: willow, poplar, miscanthus, eucalyptus and switchgrass. The environmental characteristics of the species (climate and soil requirements) were matched with the terrain conditions to derive the quantitative, spatial assessment in the form of digital maps. The analysis was performed within Geographical Information Systems (GIS), the software enabling work with spatial, attribute data and statistics.

The input special data are basically two geo-databases: TERRASTAT FAO (2002) and the European Soil Database (ESDB).

The methodology used for generating suitability maps consists of the following steps:

Step 1: Defining the Mapping Suitability Units (MSU).

- Grouping input thematic layers (thermal climates, soil depth, length of available growing period, etc.), represented in Annex D.
- Intersection input layers to merge thematic layers into a MSU map.
- Dissolving received spatial units using MSU attributes (to reduce number of polygons) and saving with individual codes and IDs.

The schematic diagram in Figure 5 presents the overview of the MSU layer building procedure.

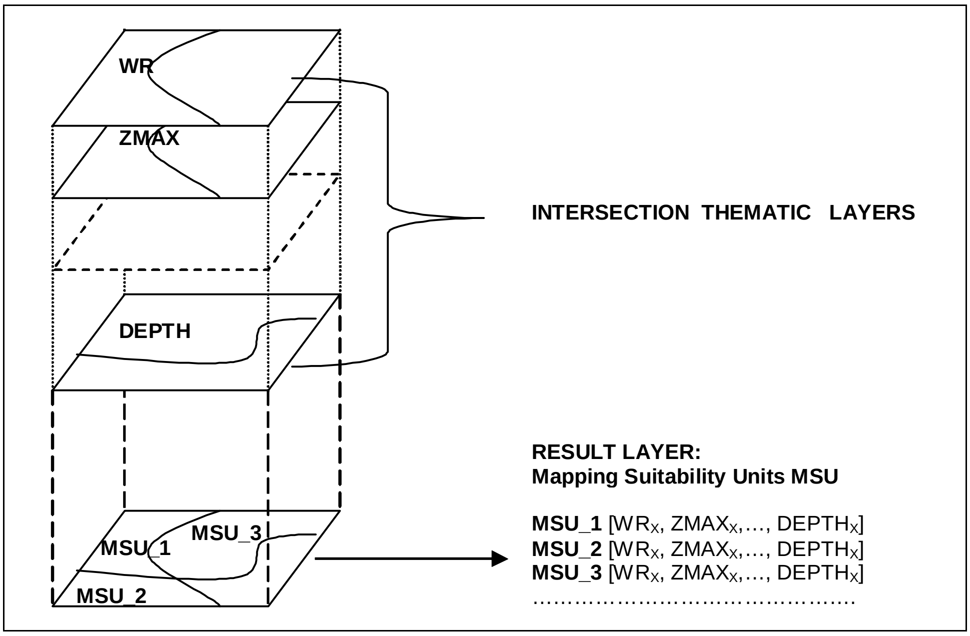


Figure 5. Generation of Mapping Suitability Units from input thematic layers

Step 2: Assessing the Suitability Values for respective crops.

- Evaluating importance (with importance weights) of the analyzed ago-climatic factors for each species.
- Evaluating suitability (with suitability weights) of respective attributes for each crop.
- Multiplying the value of factor's importance weight by suitability values for respective attributes; repeated for each attribute. Output values for each crop are represented by a respective sum of products.

The Annex E presents the evaluated agro-climatic factors and attributes. The importance weight scale for factors is 0-10 point. The attributes were evaluated with suitability weights 0-10 point scale, where 0 represents not suitable conditions and 10 refers to very suitable conditions. The final values are the sum of respective products (factors' importance weight multiplied by attribute' suitability weights). The importance and suitability assessment was based on a consultation procedure between experts from ECBREC, CRES and the Warsaw Agricultural University.

Step 3: Matching the Suitability Values (Step 1) with respective Mapping Suitability Units (Step 2).

- Assigning Suitability Values with Mapping Suitability Units.
- Linking spatial dataset with assigned Suitability Values.

Step 4: Editing suitability maps using classification schemes for mapping quantitative data.

The suitability maps present evaluation of terrain conditions for five energy crop species using four suitability classes:

- Not suitable
- Poor
- Average
- Good

There is also an additional class 'no data'. The classification is based on ready to use GIS scheme 'quartile', which makes the map comparison possible. The Annex E shows the energy crops Suitability Values distribution and thresholds for respective suitability classes.

The final suitability maps were produced as a result of calibration process. During the calibration process factors' importance weights and attributes' suitability weights were adjusted. Several 'intermediate' suitability maps were produced. Over- or under- estimation of the factors' and attributes' weights were identified when analyzing suitability maps for a given crop. The calibration process was repeated several times.

3 Results

3.1 Forestry residues and wood industry by-products

Residue biomass constitute a significant biomass potential in Europe, see Table 3.1.

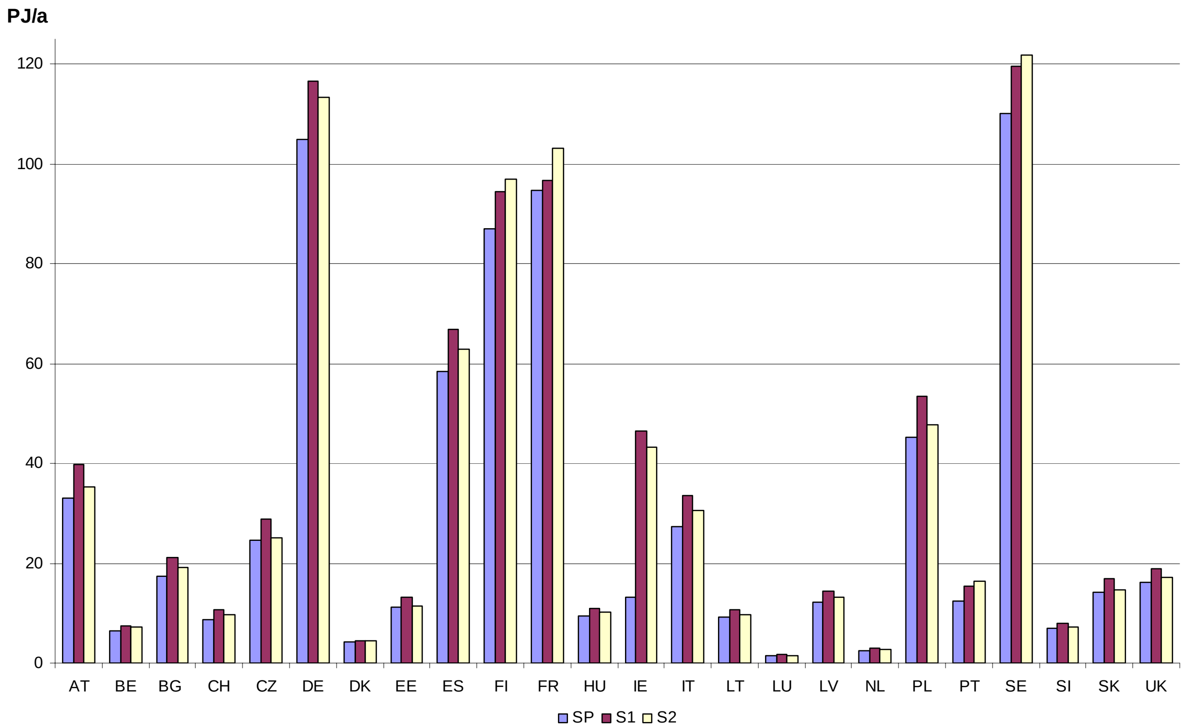
Table 3.1 Residue biomass potential in Europe

Biomass assortments	SP	S1	S2
FORESTRY WOOD	682,8	787,9	769,3
Logging residues	65,4	90,8	52,1
Thinning wood	306,8	408,9	379,2
Roots and stumps	7,6	3,4	5,1
Wood balance	303	284,8	332,9
WOOD INDUSTRY BY-PRODUCTS	50,5	67,7	57
AGRICULTURAL RESIDUES	1 831	1 566,8	1 477,8
Cereal straw	855,2	703,38	631,1
Maize straw	764,1	683,63	683,6
Oilseed straw	240,5	217	217
TOTAL	2 564,3	2 422,4	2 304,2

In the scenario S1 the biomass potential is higher for woody biomass assortments[1] than in the Starting Point. This is due to the assumptions on more intensive forest exploitation and harvesting rates in forestry. For scenario S2, in which sustainability aspects are emphasized, the available potential is lower even compared to Starting Point. For a few countries potential in S2 is higher then S1, which is due to the fact that wood balance for these countries have big share in total wood potential.

The highest potential can be found in Germany, Spain, Finland, France, Poland and Sweden, countries of large forestry areas – see Graph 3.1 and Figure 3.1.

[1] With the exception of wood balance. Generally, wood balance fraction in S2 is higher than in S1 and SP, which is due to higher volume of not harvested stands, while lower felling rate is assumed for S2 compared with SP and S1.



Graph 3.1 Biomass potentials of forestry wood and wood industry by-products (cumulated) in European countries

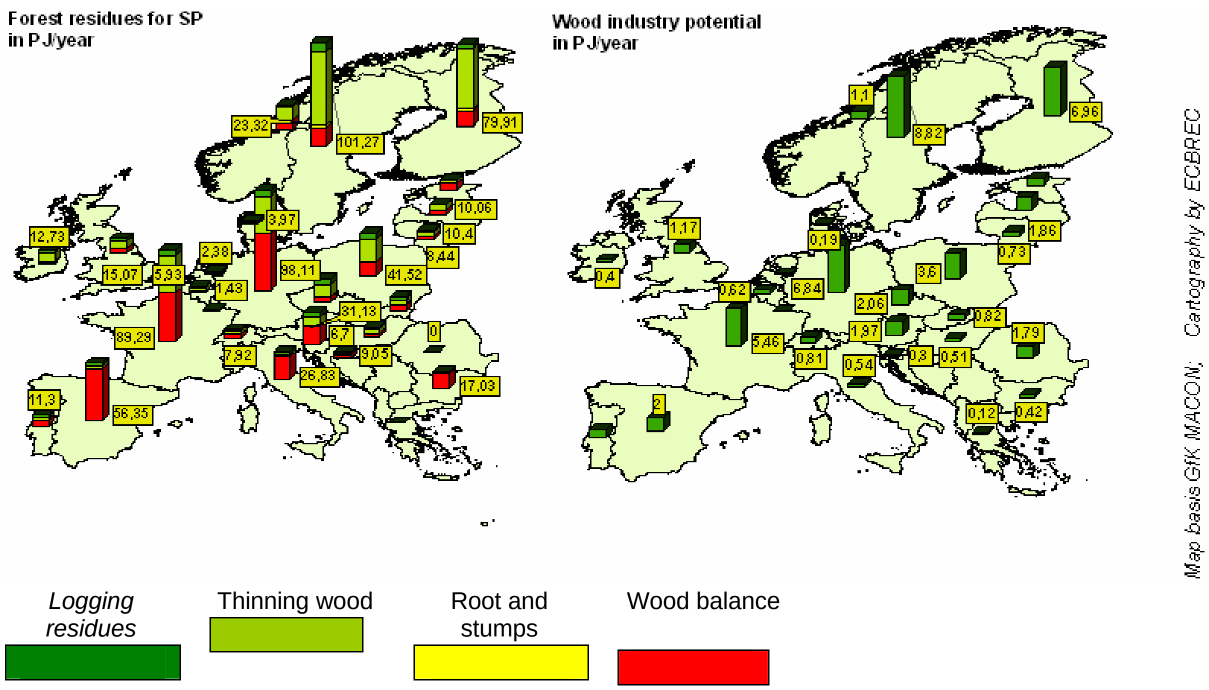


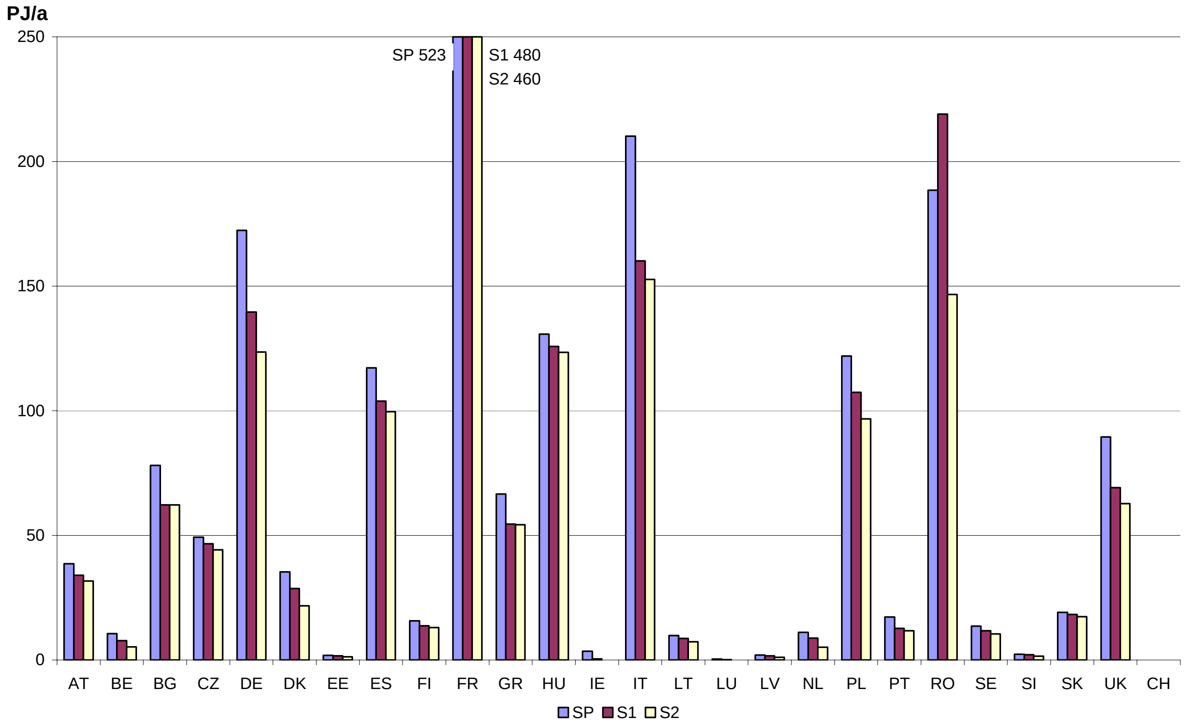
Figure 3.1 Forestry and wood industry residue potential in PJ/year in Europe

The sensitivity analysis showed the factors influencing much the available potentials. Logging residue potentials are very sensitive to the changes of the estimated factor of the share of logging residues not removed from forests. For wood industry by-products the factor for the utilization is the most important parameter affecting the available potential.

3.2 Agricultural crop residues

Large crop residue resources are found in Europe, when considering straw residues from cereals, straw from rape and residues from maize for grain. Coming from the Starting Point to the scenario S1 and S2 the potential available for energy is reduced with 11% and 20%, for S1 and S2 respectively. This is mainly caused by the introduction of cereal varieties of relatively short, even though the cereal grain yields will increase.. The difference between scenario S1 and S2 comes from the fact that in S2 more straw would be used for animal bedding compared to S1.

The highest straw potential can be found in France, a country with largest area of arable land and high grain production, then Italy, Romania, Denmark, Hungary, Poland and Spain come in the place of order, see Graph 3.2. In other countries the available straw potential is lower than 100 PJ/a for each of them. Straw deficits are in Switzerland, but it was marked as zero potential on the graph.



Graph 3.2 Agriculture crop available potential in PJ/year in European countries

The NUTS-2 regions of the highest straw availability in GJ/ha can be found in France, Italy, Hungary, Bulgaria, Denmark, Poland and Greece, see Figure 3.2.

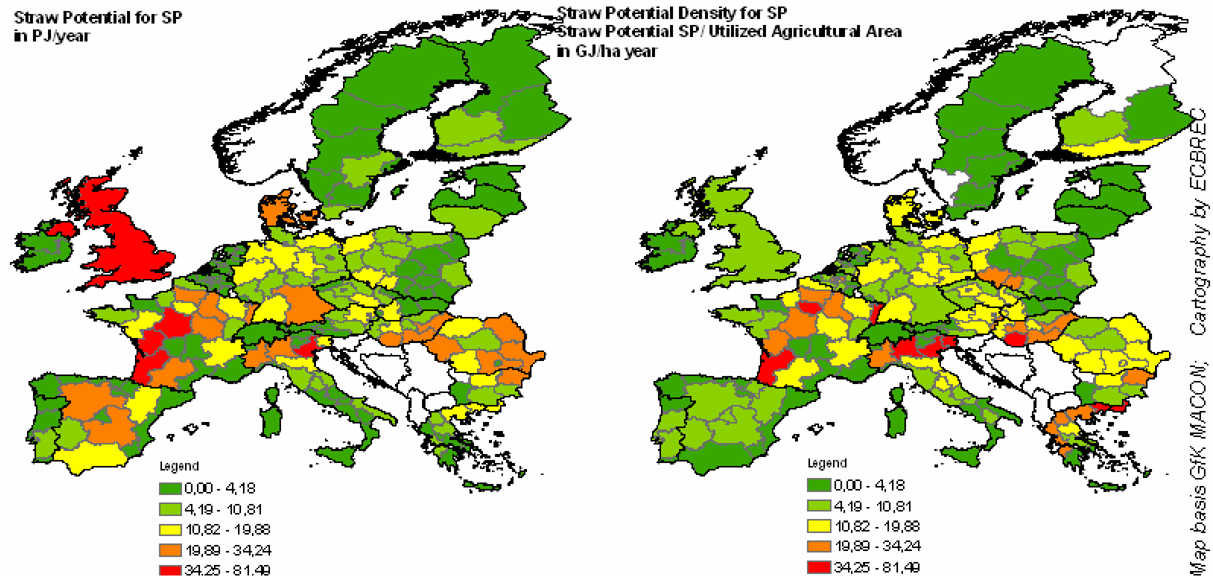


Figure 3.2 Crop residue potential density in GJ/ha*year on NUTS-2 level in Europe

The sensitivity analysis showed that the straw/grain mass ratio and factor defining the share of straw left for soil organic matter restoration are the most influencing the result of potential assessment. However, depending on the country conditions and the scenario the most sensitive parameters may be different.

3.3 Energy crops

The energy crop potential in Starting Point is estimated at the range of 1,997 – 1,420 PJ/year depending on the crop type, see Table 3.2. This is almost 100% based on the current fallow land in Europe, which exceeds 11 mln ha. The greatest amount of fallow land is found in three countries. In Spain fallow land equals 3 mln ha, in Poland and France it exceeds one million hectares, in each country. There are, however, countries where the estimated land area decreases to zero. These are Slovenia, Slovakia and Luxembourg. The availability of land reflects the total potential for energy crops.

Table 3.2 Energy crop production potential in PJ/year at country level for three types of energy crops for SP, S1, S2.

Countries	Starting Point			Scenario S1			Scenario S2		
	SRC	Miscant.	Triticale	SRC	Miscant.	Triticale	SRC	Miscant.	Triticale
AT	16,0	15,6	16,5	54,7	62,2	127,4	15,6	17,2	12,2
BE	4,9	3,9	4,5	18,4	24,6	72,2	4,7	5,5	3,9
BG	59,8	75,2	54,7	319,9	402,6	200,1	186,8	218,1	108,6
CH	0,6	0,6	0,6	25,5	30,4	58,2	2,7	3,3	2,1
CZ	13,1	16,5	12,0	166,4	229,1	112,5	75,3	102,7	50,9
DE	159,1	124,6	145,6	560,2	744,5	415,3	235,8	275,3	162,4
DK	28,2	29,4	31,0	46,8	168,2	38,8	27,6	33,0	22,9
EE	3,7	4,7	3,4	33,9	46,7	23,4	17,1	24,3	11,8
ES	624,2	672,0	342,6	995,3	1 197,7	465,8	578,3	695,6	270,3
FI	29,4	23,3	31,3	58,8	46,7	48,7	30,0	23,0	24,2
FR	237,3	185,8	217,1	711,5	1 128,6	608,9	207,7	289,5	196,8
GR	82,8	89,2	45,5	110,8	133,5	51,5	72,1	87,0	32,9
HU	26,9	33,9	24,6	288,8	446,6	222,0	120,0	186,0	90,0
IE	3,0	4,0	3,2	86,9	147,9	78,4	2,6	4,5	2,4
IT	123,1	132,5	67,6	246,2	295,3	118,4	137,7	165,5	61,3

Countries	Starting Point			Scenario S1			Scenario S2		
	SRC	Miscant.	Triticale	SRC	Miscant.	Triticale	SRC	Miscant.	Triticale
LT	21,6	27,2	19,8	107,1	148,9	73,0	52,2	72,9	35,7
LU	0,5	0,4	0,3	0,9	1,3	0,7	0,3	0,3	0,3
LV	12,8	16,1	11,7	60,2	250,6	41,0	33,5	46,7	22,9
NL	5,1	4,0	4,7	18,3	20,3	14,1	4,1	4,5	3,4
PL	232,7	293,9	212,1	682,0	957,8	463,1	350,3	494,5	238,4
PT	101,8	109,6	55,9	127,3	153,5	58,7	89,1	107,4	41,1
RO	72,5	91,3	66,4	566,8	877,6	438,0	246,2	382,7	190,0
SE	39,9	31,8	40,9	64,7	51,1	53,7	41,7	25,2	27,1
SK	0,6	0,8	0,6	76,9	105,3	52,1	35,1	48,0	23,7
SL	-	-	-	8,8	12,2	17,8	2,9	4,0	1,9
UK	7,8	10,5	7,5	9,7	14,8	7,8	6,8	10,3	5,5
Total	1 907,6	1 996,7	1 419,9	5 446,9	7 697,9	3 861,4	2 576,4	3 327,0	1 642,7

The yield level assumed for Miscanthus is the highest, thus, the potential calculated for this crop is the highest compared to the two alternatives – short rotation coppice and triticale.

The energy crop potential density in GJ per ha of total land per year calculated for each NUTS-2 region presents the average productivity of the land (including yields and the concentration of areas available for energy crops), see Figure 3.3. In the present estimation the highest level of potential density (11-25 GJ/ha) is found in the central part of Spain, southern region of Portugal, and western and southern Poland, north-west part of Bulgaria, and south-located regions of Greece. Medium energy crop potential density (6-10 GJ/ha) appears in central part of Poland, Denmark, north-east part of Germany, southern Spain, few regions in eastern Italy and one region of Greece. On the contrary, Central-south of Europe, as well as the whole UK, Ireland and almost the total area of Sweden and Finland show very low potential density.

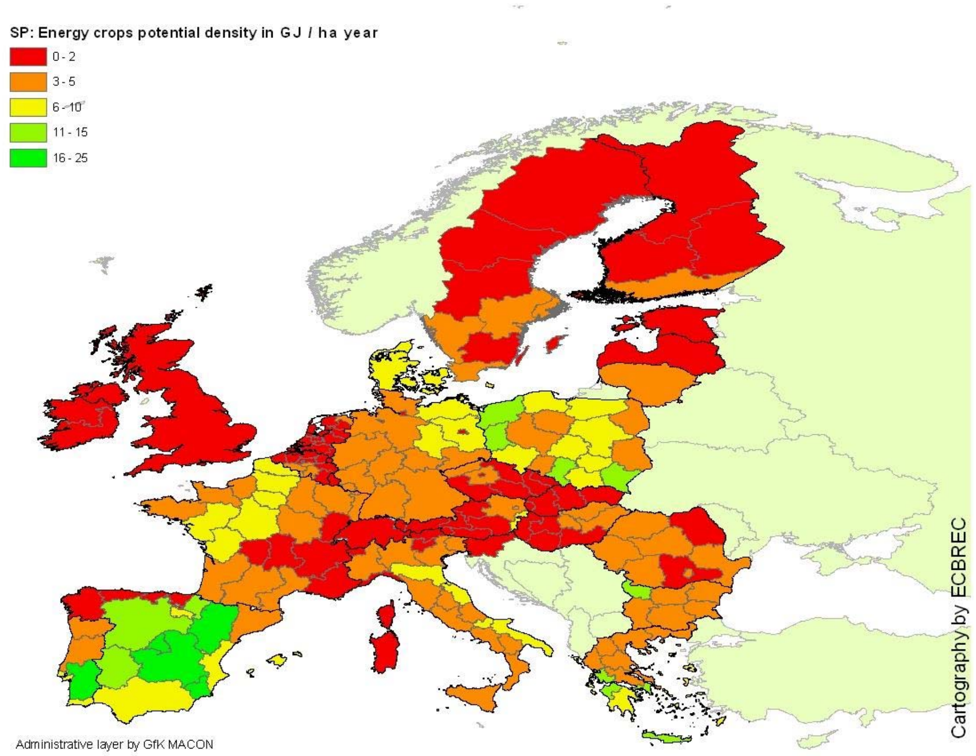
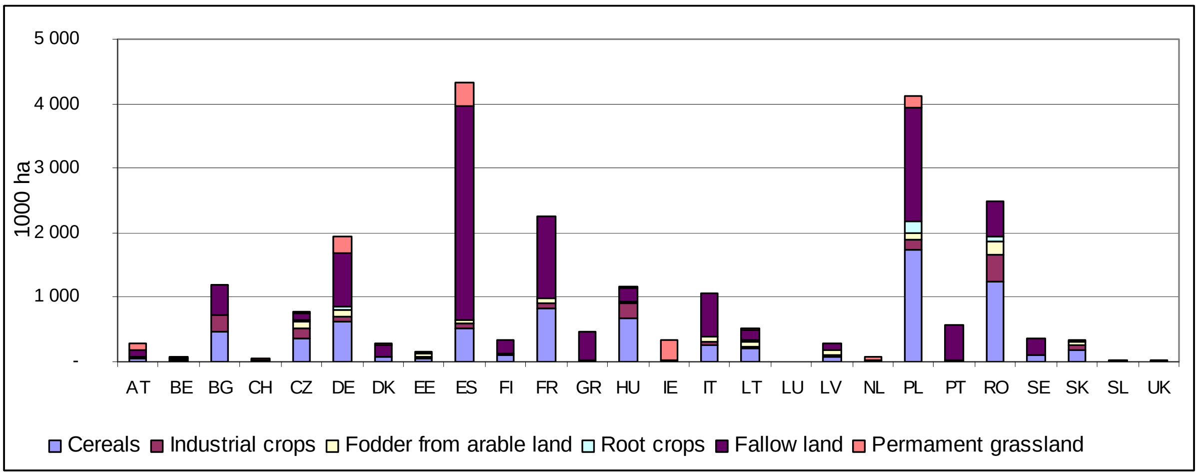


Figure 3.3 Energy crop production potential density in GJ/ha for NUTS-2 level, SP

In scenario S1 the total surplus land available for energy crops in Europe equals 23.5 mln ha. Compared to the Starting Point the increase of cultivation areas for energy crops will be possible due to the release of land from food and fodder crops. In the countries of central and Eastern

Europe, where still there is a place for crop yield growth (based on the initial level of production intensity), more land will be released than in other parts of Europe, where the yields have been already close to the technological frontier. Areas released from cereals in Poland and Romania will be over 1 mln ha, see Graph 3.3. Considerably large areas released from permanent grassland will become available in Spain, Ireland, Denmark and Poland. In Ireland there is the highest share of grassland conversion rate among all analyzed countries, amounting at 10%. The UK is the only country where there is no release from other production branches and the total surplus area consists of fallow land.



Graph 3.3 The structure of land available for energy crops in scenario S1

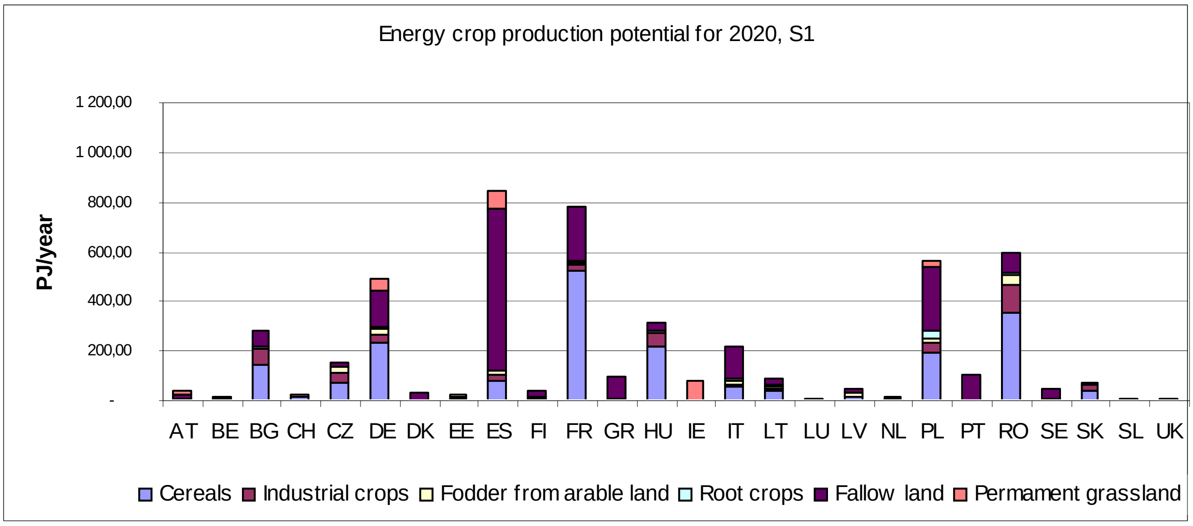
Countries with extensive agricultural system show noticeably larger area of land for energy crops per 1000 ha of total agricultural area in a country. In these countries the area of land released from food production will be larger than in countries with intensive system of agriculture. However, due to the differences in food consumption rate the final results will not show this effect.

The total production potential of energy crop in scenario S1 amounts at:

- 5,447 PJ/year for short rotation coppice,
- 7,698 PJ/year for miscanthus,
- 3,861 PJ/year for triticale whole crop.

The countries of the largest available land for energy cultivations have the highest potential of energy crops. Thus, the greatest share of energy crop potential is expected in Spain (995 PJ/year) and France (711 PJ/year), which together stand for more than 35% of energy anticipated to be gained. Significant numbers of PJ should be also obtained in Poland, Romania and Germany. Among the others are Hungary, Bulgaria, the Czech Republic and Italy.

Due to the fact that higher energy crop yields were assigned to available land areas released from arable crops than for fallow land or land released from permanent grassland, the countries with large areas released from arable crops gain more in terms of potential than countries with only fallow land or land released from grassland, see Graph 3.4. A good example here may be France and Romania, in which the energy crop production potential on land released from cereals play a great role in the overall potential. This is changing the relation among analyzed countries compared with available land potential.



Graph 3.4 The structure of energy crop potential based on land released from different crop categories in scenario S1

Energy crop potential density in Scenario S1 is much more favorable than the Starting Point with large European areas with medium (9-17 GJ/ha) to high (28-48 GJ/ha) energy crop potential density, see Figure 3.4. The highest level of potential density was found in central Spain, southern Portugal, at the whole area of Hungary, Romania and northern Bulgaria, some parts of the Czech Republic and Slovakia and one south-west region of Poland. Generally, Hungary, Poland, the Czech Republic and Romania are the countries in which the density potential is relatively high with only one region within each of the countries shows of medium or low energy crop potential density. Additionally, the north-east part of Germany and central France represent considerable energy crop potential density in this scenario.

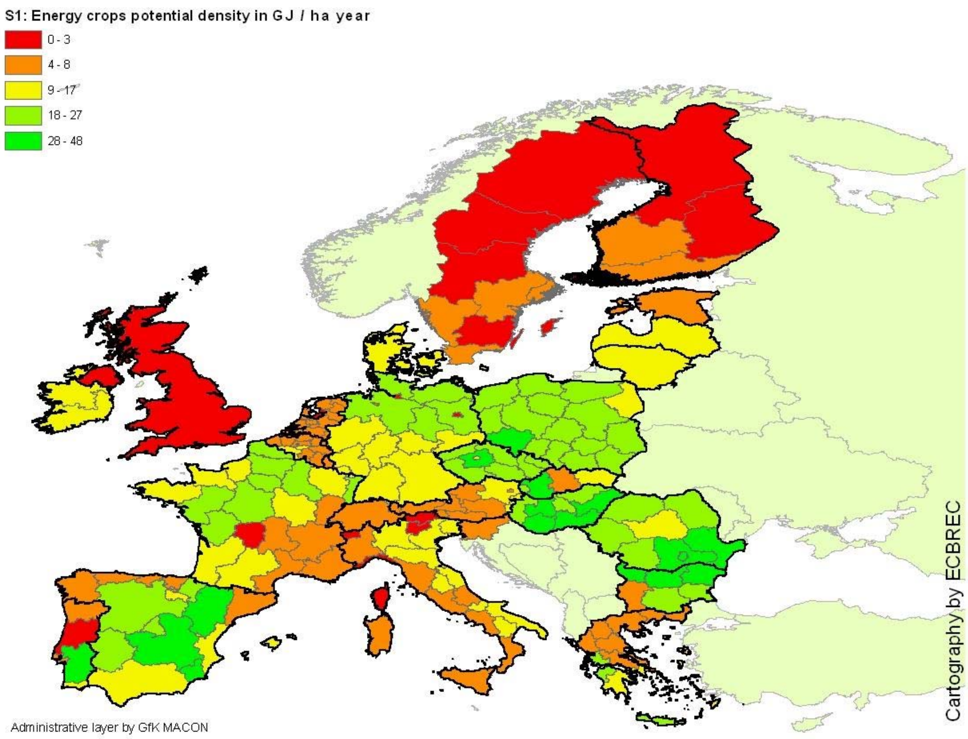
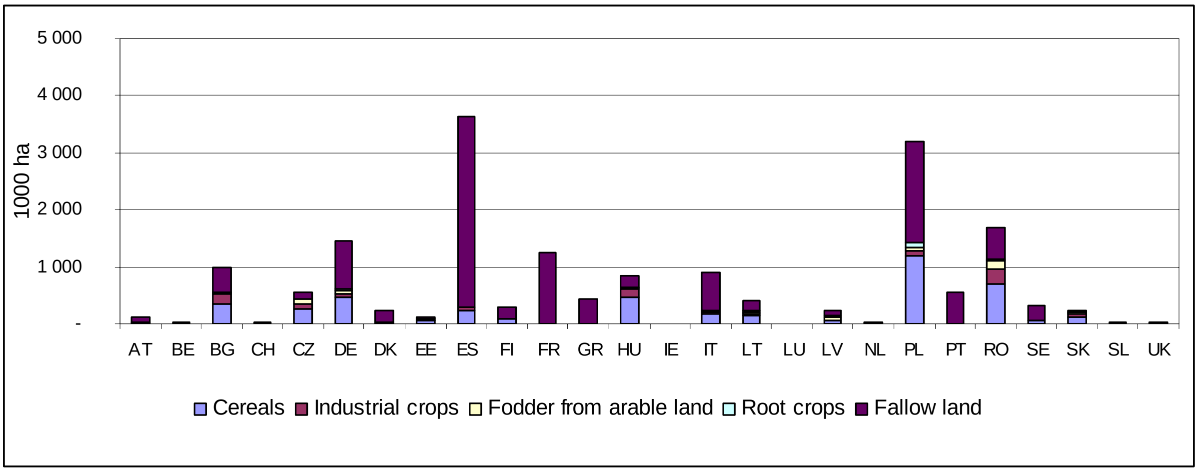


Figure 3.4 The energy crop potential density in GJ/ha at the NUTS-2 level for scenario S1

In Scenario S2 the available land area for energy crop is significantly reduced compared to S1, see Graph 3.5. Lower agriculture crop increase yield was assumed and no land is released from export surpluses compared to S1. The structure of land released from different categories changed much. The reduction in available cultivation areas compared to S1 ranges 2 - 96% in different countries.



Graph 3.5 The structure of land available for energy crops in scenario S2

The structure of land available for energy crops in Scenario S2

The total energy crop potential for S2 was estimated at:

- 2,576 PJ/year for short rotation coppice,
- 3,327 PJ/year for Miscanthus,
- 1,643 PJ/year for triticale whole crop.

The energy crop yield are reduced with 30% compared to S1. The leading potential belongs to Spain and Poland and equals 578 and 350 PJ/year, respectively. Noticeably high potential levels will be also reached in Romania, Germany, France, Bulgaria, Italy and Hungary.

The energy crop potential density at the NUTS-2 level reaches 18-28 GJ/ha per year in the north Bulgaria, southern Portugal and three central-east regions of Spain, see Figure 3.5. The total area of six countries (Lithuania, Latvia, Poland, Hungary, Romania and Bulgaria) was estimated to have medium to high potential density (6-17 GJ/ha). In the eastern and north-east Germany the potential ranges 11-17 GJ/ha. In northern and western Italy there are regions of medium potential density of 6-10 GJ/ha. In comparison to scenario S1 the greatest changes appear for Ireland, Alpine region and France.

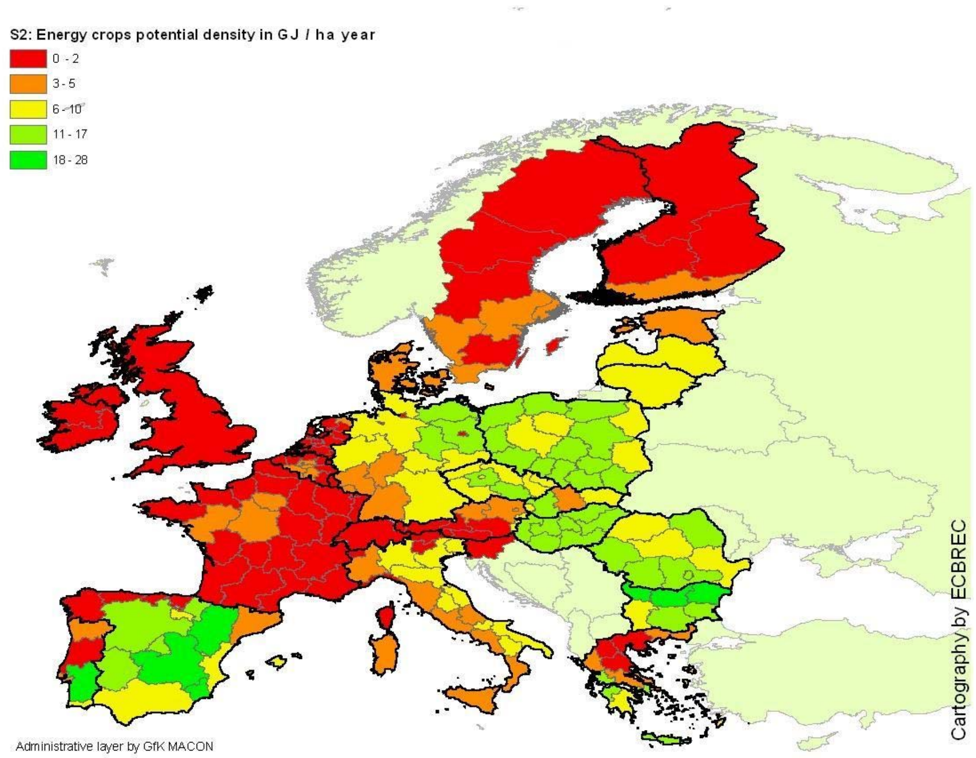


Figure 3.5 The energy crop potential density for NUTS-2 level for scenario S2

3.4 Overall assessment of biomass potential

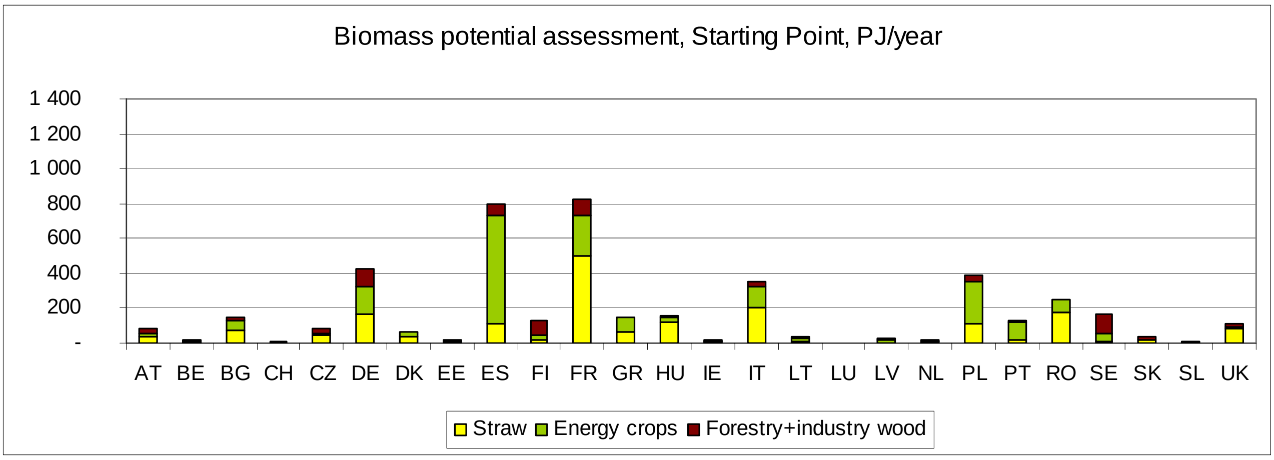
The overall biomass could supply a considerable energy potential, reaching 7,867 PJ/year in scenario S1, see Table 3.3. The biomass potential increase rate between Starting Point and Scenario S1 is at the level of 76%. Majority of the potential comes from agriculture biomass. The dominance of agricultural biomass, energy crops in particular, grows stronger over time, amounting at 84% of the total in Starting Point and 89% in scenario S1. Energy crops potential has the highest contribution to the total in all scenarios.

Table 3.3 The structure of biomass potential on pan-European level

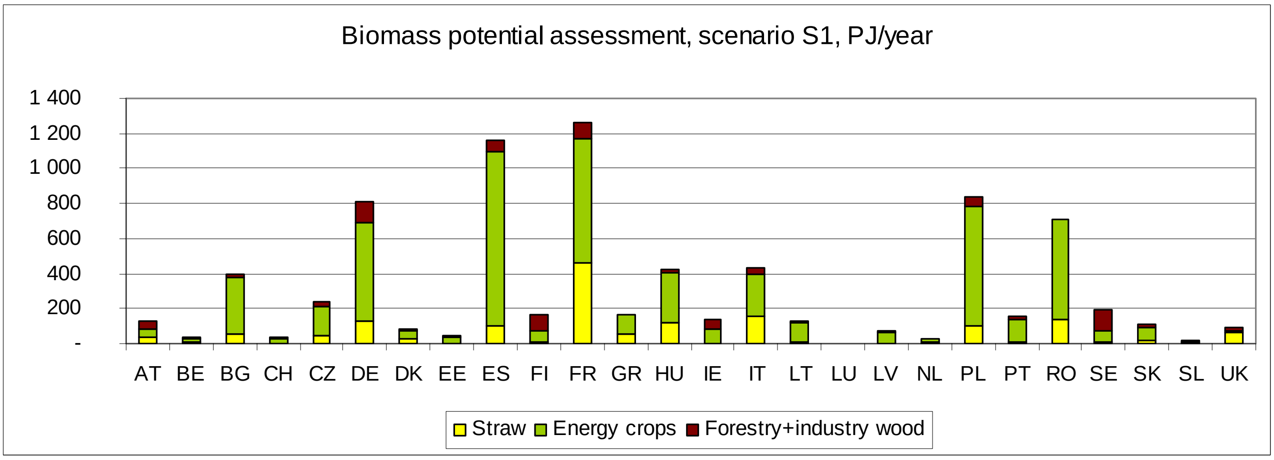
Biomass	SP	S1	S2
Energy crops	1 907,61	5 447,07	2 577,27
Agriculture crop residue	1 828,78	1 564,75	1 476,30
Forestry residue and wood industry by-products	733,30	855,63	826,35
TOTAL	4 469,69	7 867,45	4 879,92

The potential assessment in 2020 range between scenario S1 and S2, which relate to high and low level of biomass production and procurement intensity. The difference is coming mainly from the gab between the energy crop potential, which can change with 53% between S1 and S2.

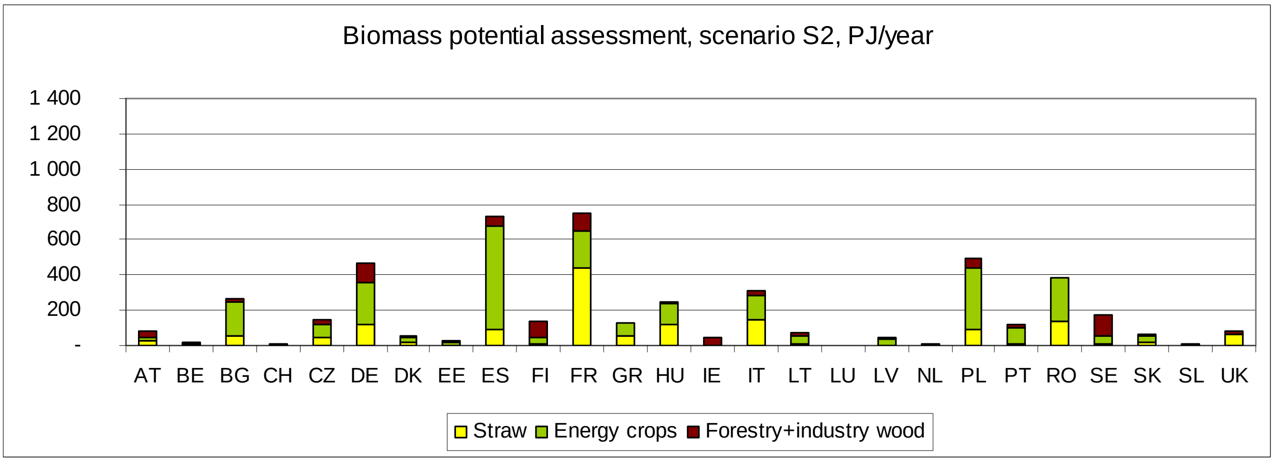
The structure of the overall potential for Starting Point and Scenario S1 and S2 is presented in Graph 3.6 - Graph 3.8.



Graph 3.6 Structure of biomass potential on country level for SP



Graph 3.7 Structure of biomass potential on country level for scenario S1



Graph 3.8 Structure of biomass potential on country level for scenario S2

Obviously geographically large countries, such as France, Spain, Poland and Romania, have the largest absolute biomass potentials. This distribution of resources is however altered when taking into account the potential density calculated over total land. NUTS-2 regions of the highest potential biomass productivity in Europe are:

- Western Poland

- Eastern Germany
- Southern Hungary
- North-west and nort-east Bulgaria
- Denmark
- Northern Italy
- Areas in France from the north-east to the south-west
- Central Spain
- Southern Portugal.

Particularly the regions of the highest potentials can be regarded as promising biofuel plant locations, they are presented in Figure 3.6.

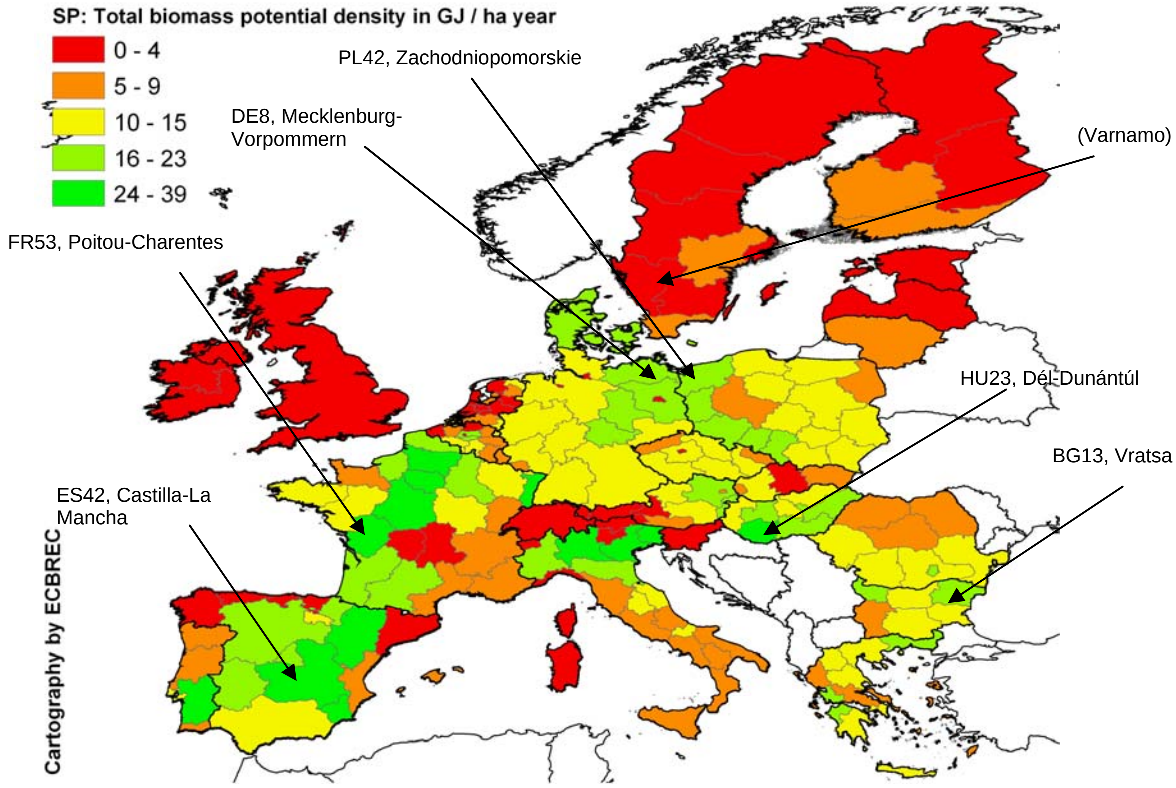


Figure 3.6 Selection of regions of the highest biomass potential density for NUTS-2 level, SP

Moreover, Table 3.4 presents land use related with the estimated biomass potentials. For energy crop it reflects the available cultivation area. For agricultural crops, this is the total cultivation area of crops of which the residues are produced. For forestry residues and wood industry by-products the relevant area of forest available for wood supply is presented.

Table 3.4 Land use under the biomass potentials in 1000 ha

	SP	S1	S2
Energy crops	11 350	23 509	17 557
Agricultural crops* (cereals, maizegrain, rape)	74 847	63 620	69 571,9
including wheat	26 447	22 480	24 583
Area of forest available for wood supply	48 567	48 567	48 567
Total	**134 764**	**135 696**	**135 696**

* cultivation area of crops relevant for the investigated residues (cereal straw, residues from maize for grain, and straw from rapeseed)

4 Discussion

4.1 Uncertainties regarding energy crop cultivation area

Total land available for energy crops have been estimated due to different factors influencing branches connected with agriculture. The assessed amounts of land for energy species consist, both on the national level and the NUTS-2 level, of land released from cereals, industrial crops, and fodder from arable land, root crops, fallow land and permanent grasslands. For all of these compounds some estimation has been established.

Land released from agricultural crops due to productivity increase has been assessed according to the predictions about biotechnology progress and improvement in production standards, which are to result in higher crop yields. As a consequence less land is expected to be necessary for food and fodder production in the future. However, the level of technical development is difficult to predict and may have different results among countries, mainly due to their economic position.

Population and diet are main factors shaping the demand for food. The population is expected to decrease moderately within the next decades in most countries (United Nations, 2003). However, for food consumption patterns the trend in Europe during the past decades was to increase the land area per calorie produced (Gerbens-Leenes and Nonhebel, 2002). This was due to growing consumption of meat, diary products and beverages. If such trend continues in Europe, the land release possible due to increased crop productivity will have to be used for animal foodstuff mainly. Such situation was analyzed by Yamamoto et al. 2001, who established a scenario for 2100, in which the energy crop potential was estimated at zero as all the land in Europe and globally was reserved for food production.

Considering the estimated food production there are also other elements that should be pondered, for example the RENEW analysis does not include factors like the changes of supply and demand for meat caused by possible outbreak of epidemic among animals.

Food production is given priority in our analysis; however, the countries are not expected to be self-sufficient in food production within the investigated time horizon. The current trends in agriculture export/import are assumed to continue until 2020. However, some changes in exports may happen due to the growing demand for grain in the developing countries of South East Asia (DG Agriculture, 2006).

In Scenario S1 the net exporting countries (cereals and meat) were assumed to convert some of the land from reducing export surpluses into bioenergy plantations. The conversion rate was assumed at 30%. However, the rate may be much less as agricultural exports are subsidized and constitute an important contribution to the national budget in some countries, e.g. Poland, Romania, and France.

The estimated available areas for energy crop production may be reduced in case a part of agricultural imports are to be produced domestically on the released land. Such assumption was not included in the potentials analysis in RENEW. This would have the strongest influence on the final result in countries, which are leading net cereal importers, e.g. Spain, Italy, The Netherlands, Belgium, and Portugal.

The land competition between energy crops and several other kinds of non-food land-uses, such as fiber, chemicals, infrastructure, afforestation schemes, nature conservations, etc. was not included in this analysis. However, regarding the biorefinery development prospects, the land use for bio-material production might also be of a growing importance in European agriculture in the future decades. Additionally the competition for land between lingo-cellulose crop and other types of energy crops was not considered.

The growing expectation with regard to biomass as a source of sustainable energy would place additional restrictions on the possible cultivation of energy crops in the next decades (Cramer et al., 2007). Large-scale energy crop production will have to comply with biodiversity, environment, traditional land use applications, local prosperity requirements, etc. This will impose additional limitations on the potentially available cultivation areas and yield achieved.

4.2 Uncertainities regarding energy crop yields

The assessment of energy gained in all the countries have been done by calculating the land available for energy crops and the possible yield to be obtained. In some countries where the amount of available land was found to be relatively big, the level of overall energy crop potential occurred to be not corresponding and on the contrary, countries with not much surplus land appeared to have higher potential. These discrepancies are resulting from two different yield levels relevant for average and poor quality soils used in the LA model. The other aspect that influenced mentioned numbers was geographical position. The same or relevant species provide various yields in different agro-climatic zones of Europe.

It is important to understand realistic differences between two scenarios presented for the future (S1 and S2). Nowadays, energy species produce changeable amounts of biomass, depending on many factors. The yields of energy species for scenario S1 were derived from deliverable D5.03.04, which shows yields of well-managed commercial plantations. The yields for 2020 were assumed due to the expected improvement in plantation management schemes and cultivation of high yielding varieties. However, it is known that due to different fertilization level as well as water, soil and climate conditions at the cultivation site, the yield gained may grow even higher or decrease significantly.

In Scenario S2 the yields were reduced with 30% compared to S1 to reflect the requirement to minimize the environmental negative effects of intense agriculture. Considering the fact that the current area of lingo-cellulose energy crop plantations in Europe is very insignificant and the analyzed time frame is relatively short, the assessment of scenario S2 may be regarded as more realistic. The experience of Swedish farmers with cultivating willow shows that the expected yields have not been achieved on commercial plantations. The yields were projected to be at the level 12 t DM per ha per year, however, they occurred to be only 6 t DM/ha on the existing plantations (Larsson, 2007).

Spain and Poland are the leading countries considering the energy crop potential. In both of them as well as in France the available land for energy crops comprises large areas of fallow land. At this point it is important to consider that in reality total fallow land cannot be completely adapted for energy plantations. Even if energy crops are assumed to be tolerant to various not appropriate conditions and do not have high soil requirements, some areas would occur to be not suitable for establishing energy plantations due to unreasonably low yields. In Poland fallow land comprises large areas of poor sandy soils with defective water conditions, which will produce extremely low yields. Similarly, in Spain large areas would require irrigation if used for energy crop plantations.

4.3 Uncertainities regarding forestry biomass supply

The supply of forest residue and wood industry by-products is dependent on the felling rate in order to supply the industrial roundwood. The supply of roundwood, however, is determined by (i) the age and species structure of forests, (ii) demand for wood products, (iii) forestry management regime. Moreover, forest residues available potential is very dependant on the residue removal rate from the felling site.

Since the 1980s there has been increasing awareness of the importance of functions of the forest other than wood production. In accordance with this, conservation of biodiversity and provision of recreation are now receiving equal attention as sustainable wood supply in forest policy objectives in all European countries. Measures as to meeting these objectives include increasing the area of nature reserves and adapting to nature-oriented management. Despite the loss of exploitable forest to nature reserves, the forest area available for wood supply is expected to remain unchanged. This is due to implementation of afforestation schemes in many European countries. Enhancing the role of nature-oriented management does not necessarily lead to a smaller supply of wood. However, it may contribute to less incentive to harvest for forest owners, which would then reduce the supply of forest residues and by-products as well. (ECE/UN-FAO, 2001)

4.4 Uncertainties regarding crop residue supply

4.5 Comparison with previous assessments

Biomass as an interesting energy source has been investigated by many research groups resulting in several studies, see Table 2.1. The studies differ in terms of approaches, main assumptions, level of analysis, time frame and the geographical scope of the assessment. The results vary widely.

In order to compare the RENEW assessment with other studies, only several studies have been chosen. The selection criteria were:

- Resource focused approach,
- Biomass categories investigated: crop residues, energy crops and forestry biomass,
- European scope of assessment,
- Studies published not earlier than 2000.

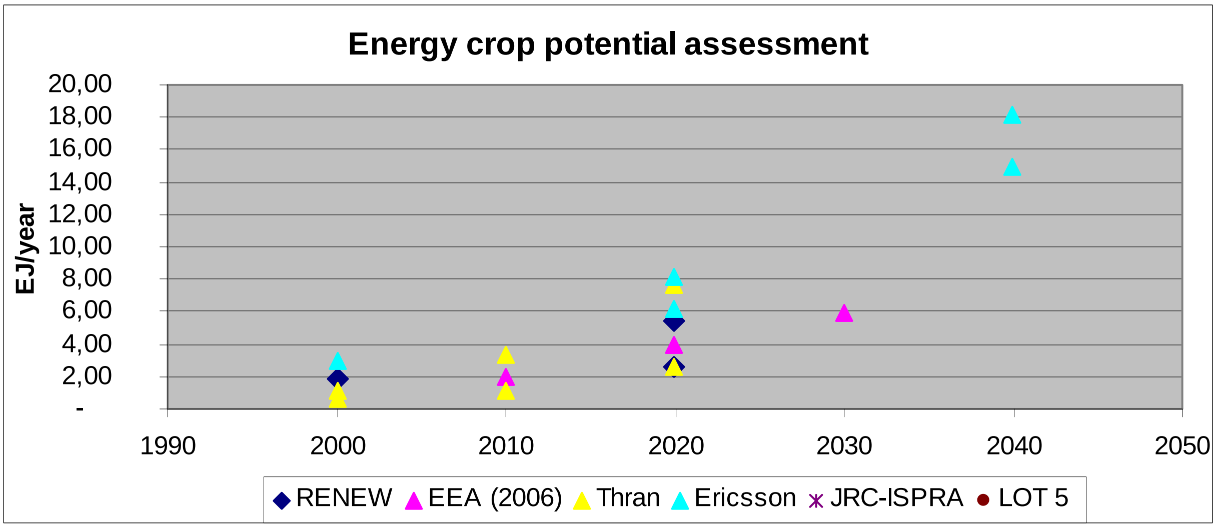
Table 4.1 Energy crop potential assessment according to RENEW and other studies; aggregated results

Study and scenario		Energy crops	Crop residues	Forestry+wood industry	TOTAL
		EJ/year	EJ/year	EJ/year	EJ/year
RENEW					
SP 2000	EU15	1,46	1,26	0,57	3,29
	EU12	0,44	0,57	0,15	1,17
S1 2020	EU15	3,11	1,07	0,66	4,84
	EU12	2,31	0,50	0,18	2,99
S2 2020	EU15	1,45	1,00	0,66	3,11
	EU12	1,12	0,48	0,16	1,75
EEA (2006)					
2010	EU15	1,15	-	1,49	2,64
	EU10	0,82	-	0,28	1,10
2020	EU15	2,50	-	1,39	3,89
	EU10	1,51	-	0,25	1,75

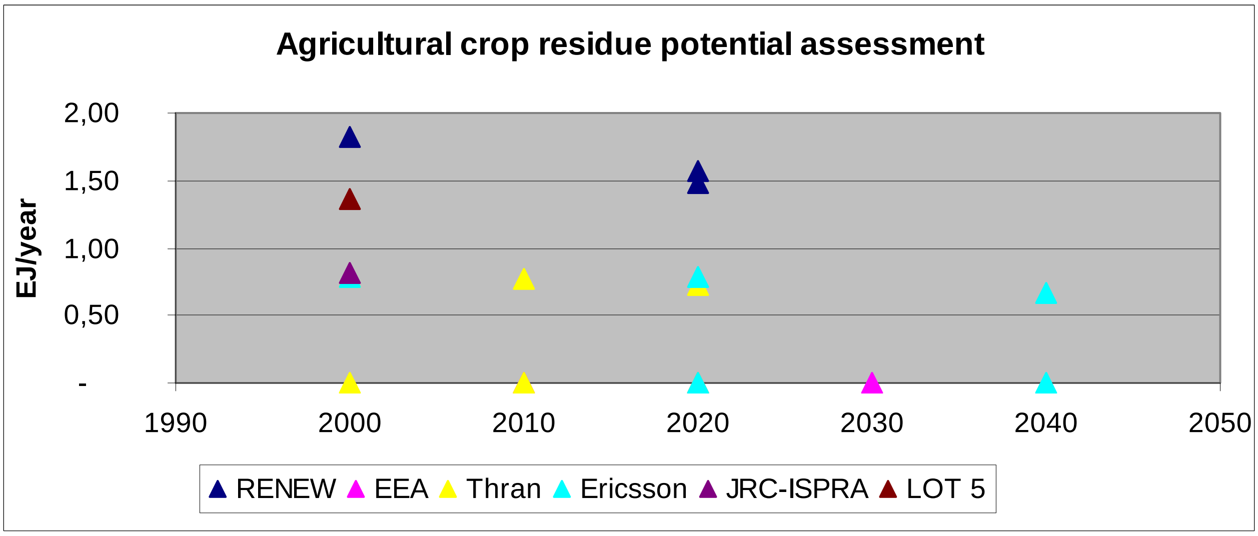
2030	EU15	3,98	-	1,39	5,37
	EU10	1,98	-	0,23	2,21
Thran at al. (2005)					
CP Scenario 2000	EU15	0,92	0,58	0,37	1,88
	EU12	0,23	0,20	0,07	0,50
E+ Scenario 2000	EU15	0,54	-	-	0,54
	EU12	0,14	-	-	0,14
CP Scenario 2010	EU15	2,56	0,58	0,43	3,57
	EU12	0,78	0,20	0,07	1,05
E+ Scenario 2010	EU15	0,79	-	-	0,79
	EU12	0,26	-	-	0,26
CP Scenario 2020	EU15	5,71	0,54	0,47	6,71
	EU12	1,92	0,19	0,08	2,19
E+ Scenario 2020	EU15	1,87	-	-	1,87
	EU12	0,68	-	-	0,68
Ericsson, Nilsson (2006)					
Scenario1 2000	EU15	1,35	0,67	1,27	3,29
	EU12	0,46	0,22	0,41	1,09
Scenario 2a 2020-2040	EU15	3,40	0,56	0,10	4,06
	EU12	1,80	0,26	0,06	2,12
Scenario 2b 2020-2040	EU15	4,10	-	1,71	5,81
	EU12	2,10	-	0,61	2,71
Scenario 3a >2040	EU15	9,40	0,52	1,27	11,19
	EU12	5,60	0,15	0,43	6,18
Scenario 3b >2040	EU15	11,30	-	1,71	13,01
	EU12	6,80	-	0,57	7,37
JRC-ISPRA					
2000	EU15		0,42	-	0,42
	EU12		0,40	-	0,40
LOT 5 (2003)	EU15		1,06	1,32	2,39
2000	EU12		0,31	0,32	0,62

Comments: in the group EU15 following countries are included: AT, BE, DK, FI, FR, DE, GR, IE, IT, LU, NL, PT, SE, UK
EU10: CZ, EE, HU, LT, LV, Pl, SK, SL
EU12: CZ, EE, HU, LT, LV, Pl, SK, SL, BG, RO

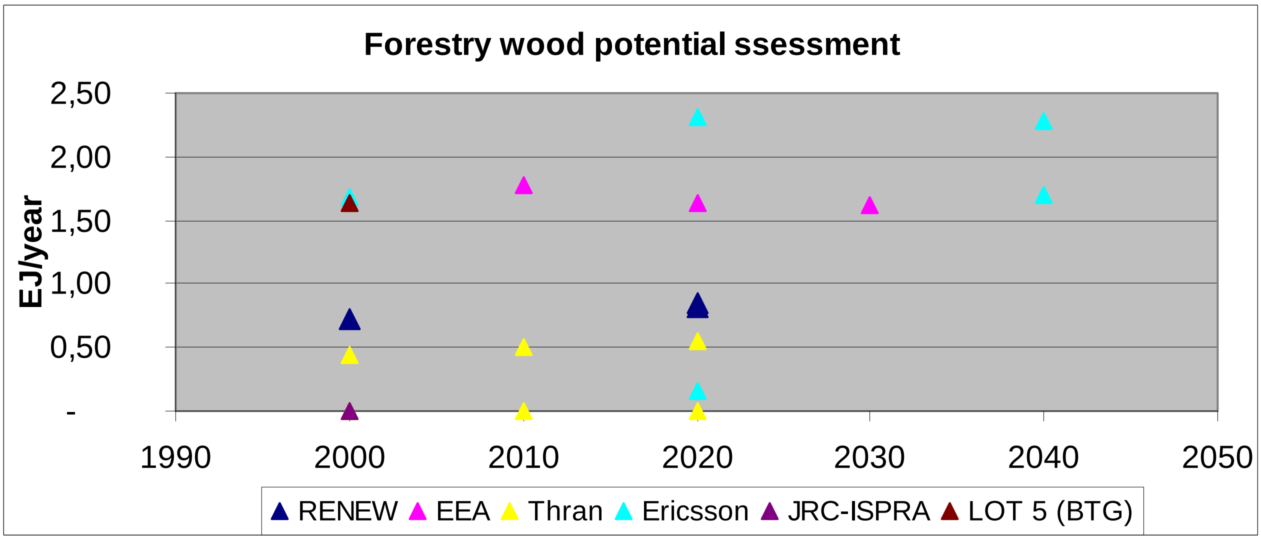
The Graph 4.1 - Graph 4.3 present the results of the studies for three biomass types.



Graph 4.1 Comparison of energy crop potential assessment by RENEW and other studies



Graph 4.2 Comparison of agriculture residue potential assessment by RENEW and other studies



Graph 4.3 Comparison of forestry biomass potential assessment by RENEW and other studies

The RENEW results for energy crops are at the similar level as for the studies of EEA, Thran at al., and Ericsson, see Graph 4.1. The greatest differences are for the crop residue assessment. RENEW is much over the other studies. For forestry biomass RENEW results are at in between the other assessments. The main reasons for the differences are the biomass fractions investigated within the biomass categories of origin and the assumptions used.

The diversity in the results and assumptions shows how different assumptions can influence the final assessment results. The results on potentials should be always accomplished with a commentary on the frame conditions of the assessment.

5 Conclusions

Agriculture and forestry sectors offer significant amounts of biomass to be available for energy use, including transportation sector in Europe. This may contribute to the reduction of greenhouse gas emission in Europe.

The estimated potential is the maximum that could be available under the scenarios' assumptions. The estimation does not include the competition from other non-food activities on agricultural land either the competition for biomass at the demand side among different sectors, e.g. electricity, heat or transportation.

Respecting the key project assumption that food and fibre production shall not be affected, the estimated biomass potential amounts at 4.47 EJ/year in the Starting Point. In the future scenario for 2020 it may range between 4.88 -7.87 EJ/year, depending on how much intense will be the biomass production and harvesting system. Majority of the estimated potential comes from agriculture biomass, with energy crops having the highest contribution to the total.

The biomass potential assessment on NUTS-2 regional level resulted in pre-selection of most productive regions, which may be possible BtL plant locations. However, in practice the biomass availability will be only one of the various criteria taken into account for the decision on the location selection of the BtL plant. Once the plant is established and the demand for biomass is strong, the biomass production may exceed the estimated potential far away in this region. Also, strong land competition should be expected. The selected locations are :

…..

The residue biomass availability is always strongly connected with the main product production. Change in roundwood harvesting rates or cereal production will result in changes in the forestry and agricultural residue amounts, respectively. Moreover, in our assessment only the surplus left after supplying the current food and fibre related needs are considered as available potential. However, with the change of biomass market price there may be reallocation of biomass uses, with possible increase of the biomass volume available for bioenergy.

The investigation of energy crop production potential reveals huge cultivation areas available for dedicated energy crop production in Europe. In the Starting Point this is the current fallow land, while in the future scenario additional land could be released due to the projected increase of cereal yields. The amount of released land is dependant on the type of agriculture production system. In the countries of central and Eastern Europe, where still there is a place for crop yield growth (production intensity increase) more land would be released than in other parts of Europe, where the yields have been already close to the technological frontier. The released land could be allocated for energy crops without affecting food supply. The projected changes in population and food consumption were taken into account.

The investigated energy crops are permanent lingo-cellulose crops, which are preferred over the annual energy crops due to better cost effectiveness and lower environmental pressure (plantation established once for several years, better efficiency in inputs management, etc.) However, short rotation coppice (willow, poplar, eucalyptus) and crops such as Miscanthus are a new type of crops for conventional farmers in Europe. This means an external support would be required to the farmers to spread the knowledge and experience in order to develop high productive and properly managed commercial plantations.

Currently the lingo-cellulose energy crop area in Europe amounts less than 100,000 ha in total. This emphasize the need for very effective implementation strategies to meet the energy crop production potential in Europe, which will be necessary to achieve the renewable energy targets established for 2010 and 2020. Among various implementation issues the competitiveness of energy crops over conventional crops is regarded as most crucial factor in the initial phase.

Common Agricultural Policy is expected to affect the energy crop sector development much. This is due to the fact that the agriculture sector in Europe is highly influenced by CAP regulations. In particular, set-aside obligation and any payments directed to energy crops cultivation have strong impact on the energy crop cultivation development, which is proved by the current energy crop production for the1st generation biofuels.

The world is changing much, and even though a relatively short time frame was investigated in the RENEW project, there might be large changes in the overall situation of food and bioenergy production and consumption in Europe. If biomass for energy related needs, such as BtL fuels, are used to a significant extend in the future, this will have definitive effects on the food market. It can affect food production and further result in corresponding effects in agriculture biomass production potential. However, this was out of the scope of RENEW assessment.

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Appendix 1: Biomass potential assessment results - tables

Table 0.1 Agriculture crop residue potential assessemnt results

	Starting Point	Scenario S1	Scenario S2
AT	36,66	32,33	30,15
BE	10,06	7,42	4,97
BG	74,09	59,14	59,14
CH	0,00	0,00	0,00
CZ	46,79	44,32	41,99
DE	163,64	132,58	117,27
DK	33,55	27,26	20,69
EE	1,79	1,60	1,23
ES	111,29	98,59	94,55
FI	14,93	13,08	12,38
FR	496,47	456,06	438,23
GR	63,22	51,79	51,59
HU	124,13	119,45	117,13
IE	3,38	0,47	0,00
IT	199,48	152,03	144,95
LT	9,38	8,21	6,97
LU	0,35	0,12	0,00
LV	1,90	1,61	1,07
NL	10,54	8,42	5,69
PL	115,79	101,98	91,84
PT	16,39	12,10	11,17
RO	178,86	142,02	139,23
SE	12,88	11,18	9,99
SK	18,20	17,33	16,52
SL	0,00	0,00	0,00
UK	85,01	65,66	59,55
EUROPE	**1 829,78**	**1 565,75**	**1 476,30**

Table 0.2 Forestry and wood industry residue potential assessment results

A: forestry residue

B: wood industry by-products

C =A+B

	Starting Point			Scenario S1			Scenario S2		
	A	B	C	A	B	C	A	B	C
AT	31,13	1,97	33,1	37,3	2,46	39,8	33,11	2,05	35,2
BE	5,93	0,62	6,6	6,45	0,89	7,3	6,66	0,65	7,3
BG	17,03	0,42	17,5	20,49	0,64	21,1	18,49	0,55	19,0
CH	7,92	0,81	8,7	9,68	1	10,7	8,79	0,83	9,6
CZ	22,53	2,06	24,6	25,79	3,03	28,8	22,58	2,60	25,2
DE	98,11	6,84	105,0	107,86	8,66	116,5	106,22	7,10	113,3
DK	3,97	0,19	4,2	4,25	0,24	4,5	4,21	0,20	4,4
EE	10,06	1,17	11,2	11,37	1,75	13,1	9,93	1,50	11,4
ES	56,35	2	58,4	63,87	2,97	66,8	60,28	2,55	62,8
FI	79,91	6,96	86,9	85,58	8,96	94,5	89,41	7,47	96,9
FR	89,29	5,46	94,8	90	6,74	96,7	97,45	5,71	103,2
GR	0,00	0,12	0,1	0,00	0,19	0,2	0,00	0,16	0,2
HU	9,05	0,51	9,6	10,29	0,76	11,1	9,47	0,65	10,1
IE	12,73	0,4	13,1	45,86	0,5	46,4	42,91	0,42	43,3
IT	26,83	0,54	27,4	32,66	0,83	33,5	29,77	0,71	30,5
LT	8,44	0,73	9,2	9,55	1,08	10,6	8,67	0,93	9,6
LU	1,43	0,04	1,5	1,63	0,04	1,7	1,47	0,04	1,5
LV	10,4	1,86	12,3	11,78	2,72	14,5	10,75	2,33	13,1
NL	2,38	0,12	2,5	2,81	0,12	2,9	2,58	0,12	2,7
PL	41,52	3,6	45,1	47,96	5,4	53,4	43,08	4,63	47,7
PT	11,3	1,17	12,5	13,66	1,82	15,5	14,84	1,56	16,4
RO	0,00	1,79	1,79	0,00	2,60	2,60	0,00	2,23	2,23
SE	101,27	8,82	110,1	108,37	11,22	119,6	112,42	9,35	121,8
SK	13,46	0,82	14,3	15,77	1,23	17,0	13,52	1,06	14,6
SL	6,70	0,30	7,00	7,57	0,44	8,01	6,71	0,38	7,09
UK	15,07	1,17	16,2	17,33	1,46	18,8	16,03	1,22	17,3
EUROPE	682,81	50,49	733,3	787,88	67,75	855,63	769,35	57,00	35,2

Table 0.3 **Land available for energy crops in 1000 ha in Starting Point**

Countries	Current ligno-celluelose crop plantations	Fallow land	Total available land
AT		106,3	106,3
BE		26,3	26,3
BG		454,1	454,1
CH		4,0	4,0
CZ		99,7	99,7
DE		846,3	846,3
DK		200,0	200,0
EE		28,3	28,3
ES		3 320,2	3 320,2
FI	9,0	202,0	211,0
FR		1 262,4	1 262,4
GR		440,5	440,5
HU		204,7	204,7
IE		14,4	14,4
IT		654,8	654,8
LT		164,5	164,5
LU		1,7	1,7
LV		97,3	97,3
NL		27,2	27,2
PL	7,0	1 761,5	1 768,5
PT		541,6	541,6
RO		551,2	551,2
SE	18,5	264,5	283,0
SK		4,6	4,6
SL		-	-
UK	4,5	33,4	37,9
Total	39,0	11 311,2	11 350,2

Table 0.4 **Land available for energy crops in 1000 ha in Scenario S1**

Countries	Cereals	Industrial crops	Fodder from arable land	Root crops	Fallow land	Permanent grassland	Total available land
AT	64,0	3,6	3,8	1,7	106,3	94,8	274,2
BE	3,3	0,9	8,6	5,1	26,3	26,3	70,5
BG	454,6	267,4	-	11,0	454,1	-	1 187,0
CH	18,3	0,8	-	0,6	4,0	32,8	56,5
CZ	364,0	144,3	112,1	22,8	99,7	27,0	769,8
DE	611,8	82,7	106,8	48,5	846,3	249,1	1 945,1
DK	66,6	-	-	-	200,0	18,4	284,9
EE	64,1	14,2	54,8	4,6	28,3	-	165,9
ES	507,0	87,7	50,0	11,0	3 320,2	349,5	4 325,3
FI	105,3	4,3	20,9	2,1	202,0	-	334,5
FR	837,6	74,9	62,9	10,4	1 262,4	-	2 248,2
GR	13,6	8,3	1,3	1,9	440,5	-	465,6
HU	684,6	210,8	20,4	17,6	204,7	31,8	1 169,9
IE	3,3	-	-	-	14,4	320,6	338,3
IT	269,5	39,9	77,6	11,2	654,8	-	1 052,9
LT	200,4	25,5	77,2	24,3	164,5	29,1	520,9
LU	2,6	0,2	0,9	0,0	1,7	-	5,5
LV	90,6	7,4	73,5	15,4	97,3	-	284,2
NL	4,6	0,0	4,3	1,2	27,2	42,3	79,6
PL	1 733,6	150,8	106,2	193,2	1 761,5	183,6	4 128,9
PT	26,7	-	-	-	541,6	-	568,3
RO	1 236,4	420,8	214,6	61,5	551,2	-	2 484,6
SE	91,5	-	-	-	264,5	-	356,0
SK	180,2	75,9	52,8	11,2	4,6	-	324,6
SL	19,2	4,5	-	1,0	-	9,3	34,0
UK	-	-	-	-	33,4	-	33,4
Total	7 653,3	1 624,8	1 048,6	456,2	11 311,2	1 414,5	23 508,6

Table 0.5 **Land available for energy crops in 1000 ha in Scenario S1**

Countries	Cereals	Industrial crops	Fodder from arable land	Root crops	Fallow land	Permanent grassland	Total available land
AT	17,4	0,0	0,0	0,0	106,3	0,0	123,7
BE	9,6	0,1	0,7	0,7	26,3	0,0	37,4
BG	335,5	197,6	0,0	8,1	454,1	0,0	995,3
CH	11,8	0,0	0,0	0,0	4,0	0,0	15,8
CZ	257,5	93,6	72,7	14,6	99,7	0,0	538,0
DE	463,4	49,0	63,3	27,1	846,3	0,0	1 449,0
DK	18,7	0,0	0,0	0,0	200,0	0,0	218,7
EE	46,2	9,5	36,7	3,1	28,3	0,0	123,8
ES	236,4	40,7	23,2	4,4	3 320,2	0,0	3 624,9
FI	74,1	0,6	2,9	0,4	202,0	0,0	280,0
FR	0,0	0,0	0,0	0,0	1 262,4	0,0	1 262,4
GR	0,0	0,0	0,0	0,0	440,5	0,0	440,5
HU	476,6	132,2	12,8	11,0	204,7	0,0	837,3
IE	0,0	0,0	0,0	0,0	14,4	0,0	14,4
IT	175,2	22,9	35,1	4,2	654,8	0,0	892,2
LT	146,4	16,6	50,5	15,8	164,5	0,0	393,8
LU	0,0	0,0	0,1	0,0	1,7	0,0	1,9
LV	67,2	5,4	53,6	10,9	97,3	0,0	234,4
NL	5,1	0,0	0,0	0,0	27,2	0,0	32,3
PL	1 186,4	81,3	57,3	110,1	1 761,5	0,0	3 196,6
PT	14,5	0,0	0,0	0,0	541,6	0,0	556,1
RO	701,2	265,9	135,6	39,1	551,2	0,0	1 693,0
SE	61,5	0,0	0,0	0,0	264,5	0,0	326,0
SK	125,2	49,1	34,1	7,3	4,6	0,0	220,3
SL	12,3	2,6	0,0	0,6	-	0,0	15,5
UK	0,0	0,0	0,0	0,0	33,4	0,0	33,4
Total	4 442,4	967,2	578,5	257,4	11 311,2	0,0	17 556,8

Table 0.6 Energy crop production potential in Europe, PJ/year

Countries	Starting Point			Scenario S1			Scenario S2		
	SRC	Miscanthus	Triticale	SRC	Miscanthus	Triticale	SRC	Miscanthus	Triticale
AT	16,0	15,6	16,5	54,7	62,2	127,4	15,6	17,2	12,2
BE	4,9	3,9	4,5	18,4	24,6	72,2	4,7	5,5	3,9
BG	59,8	75,2	54,7	319,9	402,6	200,1	186,8	218,1	108,6
CH	0,6	0,6	0,6	25,5	30,4	58,2	2,7	3,3	2,1
CZ	13,1	16,5	12,0	166,4	229,1	112,5	75,3	102,7	50,9
DE	159,1	124,6	145,6	560,2	744,5	415,3	235,8	275,3	162,4
DK	28,2	29,4	31,0	46,8	168,2	38,8	27,6	33,0	22,9
EE	3,7	4,7	3,4	33,9	46,7	23,4	17,1	24,3	11,8
ES	624,2	672,0	342,6	995,3	1 197,7	465,8	578,3	695,6	270,3
FI	29,4	23,3	31,3	58,8	46,7	48,7	30,0	23,0	24,2
FR	237,3	185,8	217,1	711,5	1 128,6	608,9	207,7	289,5	196,8
GR	82,8	89,2	45,5	110,8	133,5	51,5	72,1	87,0	32,9
HU	26,9	33,9	24,6	288,8	446,6	222,0	120,0	186,0	90,0
IE	3,0	4,0	3,2	86,9	147,9	78,4	2,6	4,5	2,4
IT	123,1	132,5	67,6	246,2	295,3	118,4	137,7	165,5	61,3
LT	21,6	27,2	19,8	107,1	148,9	73,0	52,2	72,9	35,7
LU	0,5	0,4	0,3	0,9	1,3	0,7	0,3	0,3	0,3
LV	12,8	16,1	11,7	60,2	250,6	41,0	33,5	46,7	22,9
NL	5,1	4,0	4,7	18,3	20,3	14,1	4,1	4,5	3,4
PL	232,7	293,9	212,1	682,0	957,8	463,1	350,3	494,5	238,4
PT	101,8	109,6	55,9	127,3	153,5	58,7	89,1	107,4	41,1
RO	72,5	91,3	66,4	566,8	877,6	438,0	246,2	382,7	190,0
SE	39,9	31,8	40,9	64,7	51,1	53,7	41,7	25,2	27,1
SK	0,6	0,8	0,6	76,9	105,3	52,1	35,1	48,0	23,7
SL	-	-	-	8,8	12,2	17,8	2,9	4,0	1,9
UK	7,8	10,5	7,5	9,7	14,8	7,8	6,8	10,3	5,5
Total	1 907,6	1 996,7	1 419,9	5 446,9	7 697,9	3 861,4	2 576,4	3 327,0	1 642,7

Table 0.7 Biomass potential assessment results for different biomass resources for each country and scenario, in PJ/year

	Starting Point				Scenario S1				Scenario S2			
	Crop residue	Energy crops	Wood residue	TOTAL	Crop residue	Energy crops	Wood residue	TOTAL	Crop residue	Energy crops	Wood residue	TOTAL
AT	36,66	15,98	33,10	85,74	32,33	54,71	39,76	126,80	30,15	15,64	35,16	80,95
BE	10,06	4,94	6,55	21,55	7,42	18,42	7,34	33,18	4,97	4,73	7,31	17,01
BG	74,09	59,75	17,45	151,29	59,14	319,91	21,13	400,18	59,14	186,85	19,04	265,03
CH	0,00	0,60	8,73	9,33	0,00	25,50	10,68	36,18	0,00	2,66	9,62	12,28
CZ	46,79	13,12	24,59	84,50	44,32	166,40	28,82	239,54	41,99	75,30	25,18	142,47
DE	163,64	159,10	104,95	427,69	132,58	560,16	116,52	809,26	117,27	235,78	113,32	466,37
DK	33,55	28,19	4,16	65,90	27,26	46,84	4,49	78,59	20,69	27,63	4,41	52,73
EE	1,79	3,72	11,23	16,74	1,60	33,86	13,12	48,58	1,23	17,09	11,43	29,75
ES	111,29	624,19	58,35	793,83	98,59	995,31	66,84	1 160,74	94,55	578,31	62,83	735,69
FI	14,93	29,40	86,87	131,20	13,08	58,79	94,54	166,41	12,38	29,97	96,88	139,23
FR	496,47	237,32	94,75	828,54	456,06	711,46	96,74	1 264,26	438,23	207,66	103,16	749,05
GR	63,22	82,81	0,12	146,15	51,79	110,84	0,19	162,82	51,59	72,46	0,16	124,21
HU	124,13	26,94	9,56	160,63	119,45	288,77	11,05	419,27	117,13	119,96	10,12	247,21
IE	3,38	2,98	13,13	19,49	0,47	86,92	46,36	133,75	0,00	2,62	43,33	45,95
IT	199,48	123,10	27,37	349,95	152,03	246,24	33,49	431,76	144,95	137,73	30,48	313,16
LT	9,38	21,64	9,17	40,19	8,21	107,08	10,63	125,92	6,97	52,24	9,60	68,81
LU	0,35	0,46	1,47	2,28	0,12	0,94	1,67	2,73	0,00	0,34	1,51	1,85
LV	1,90	12,80	12,26	26,96	1,61	60,18	14,50	76,29	1,07	33,52	13,08	47,67
NL	10,54	5,11	2,50	18,15	8,42	18,29	2,93	29,64	5,69	4,47	2,70	12,86
PL	115,79	232,73	45,12	393,64	101,98	682,00	53,36	837,34	91,84	350,33	47,71	489,88
PT	16,39	101,82	12,47	130,68	12,10	127,28	15,48	154,86	11,17	89,09	16,40	116,66
RO	178,86	72,54	1,79	253,19	142,02	566,82	2,60	711,44	139,23	246,16	2,23	387,62
SE	12,88	39,90	110,09	162,87	11,18	64,89	119,59	195,66	9,99	41,96	121,77	173,72
SK	18,20	0,61	14,28	33,09	17,33	76,95	17,00	111,28	16,52	35,08	14,58	66,18
SL	-	-	7,00	7,00	-	8,83	8,01	16,84	0,00	2,91	7,09	10,00
UK	85,01	7,84	16,24	109,09	65,66	9,68	18,79	94,13	59,55	6,78	17,25	83,58
EUROPE	**1 828,78**	**1 907,61**	**733,30**	**4 469,69**	**1 564,75**	**5 447,07**	**855,63**	**7 867,45**	**1 476,30**	**5 447,07**	**855,63**	**7 867,45**