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Renewable fuels for advanced powertrains

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THE REVIEW – BIOMASS RESOURCES AND POTENTIALS ASSESSMENT - REGIONAL STUDIES AND EXPERIENCES

Deliverable WP5.1 / D 5.1.1

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PREFACE

The following report was prepared under the FP6 integrated project RENEW, covering first 6-months project works dated from 01 January until 30 July 2004 provided by the WP5.1 Biomass resources and potentials assessment team.

WP5.1. Team and regional review responsibilities

ECBREC – EC Baltic Renewable Energy Centre, Warsaw PL	[CEE-8 countries]
CRES – Centre for Renewable Energy Sources, GR	[Southern EU]
LU – Environmental and Energy Sys. Studies Dep., Lund University SE	[North countries]
UCD – National University of Ireland, Dublin IR	[UK Islands]
IE – Institute for Energy and Environment Leipzig DE	[Western EU]
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Biomass contribution to the EU-25 energy supply has been growing since decades. White Paper goals and renewable energy development targets underlines challenges for bio-energy increase for heat production, electricity as well as for transportation fuels production. One of the main challenges is the development of biomass production and supply for all competing sectors in future. To address issues related to the assessment of future biomass production for transportation fuels in Europe we reviewed biomass resources in EU-25 and studies on potentials assessment. We hope the automotive industry and RENEW project team will benefit from the comparison of biomass supply from forestry residues, wood industry residues, agriculture residues (straw, permanent crops-field residues) and energy crops.

The aim of the report was to screen, review and gather knowledge of ligno-cellulose biomass in Europe. The biomass potentials were estimated on the basis of exploitable forestry areas, agriculture areas as well as current biomass production for different markets. Also a review of lingo-cellulose energy crops researches and cultivation practices was performed in order to revise crops species and cultivation opportunities in 5 European regions. The review work can be considered as an input for the perspectives of BtL (Biomass to Liquid) fuels production as it provides information on different biomass resources potential available within five Eropean regions.

The report contains the review of definitions of biomass potentials used in different studies, review of bio-resources databases (of European, regional or national scope), review of national studies and European research projects in which biomass potentials were investigated.

Main focus of the *REVIEW REPORT* was aimed at the lingo-cellulose biomass resources assessment incl.:

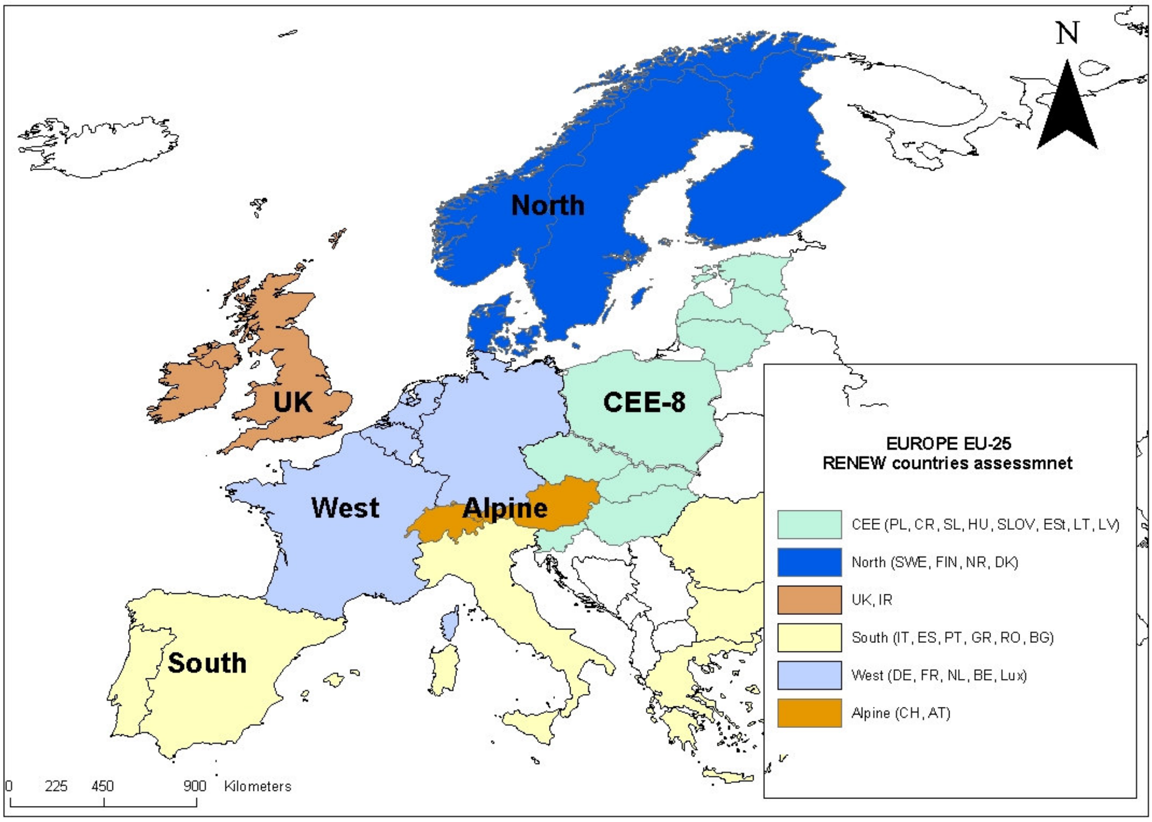
i. agriculture by-products – cereals straw (wheat, rye, barley, oats, etc.), straw from oil-seed crops (rape, etc.), other lingo-cellulose by-products (corn stalks, cotton residues, etc.)
ii. olive, vineyard and fruit tree residue – Southern Europe (peaches, apricots, olive tree pruning, etc.) and fruit processing industry – Southern Europe (seeds, stone/kernels, olive cakes, rape cakes, nuts, etc.)

iii. forestry residues: (i) logging residues from final felling and (ii) thinning residues from operations of young forests (early thinning, clear-cuttings, pre-commercial thinning of small-diameter trees)

iv. wood industry by-products (pure woody origin such as logs, sawdust, wood-chips, shavings excluding: contaminated by-products from furniture-making, wood-boards production etc.)

We decided to exclude less-promising resources of biomass from the study, respectively used wood (used wood from communal use, building materials and industry), chemically treated wood industry by-products (i.e. from furniture-industry), landscape management biomass: *woody residues, grasses etc*). We think the potentials of this biomass origin are rather limited and in parallel some of the resources (i.e. chemically treated used wood), might contains chemical impurities. Black-liquor potentials were excluded from the assessment at this project level, as this will be investigated at the later steps in 2005-2006 years.

Detailed assessment of **energy crops perspectives** will be performed in further years of the project: 2005-2006. However, in this report most promising species of woody energy crops and herbaceous (annual and perennial) energy crops were presented. Further perspectives of energy crops growing in Europe were discussed according to the current R&D trials. WP 5.1 team aimed that the results will help to define recommendations on specific energy crops species for the technological tests and for optimising BtL fuels production pathways.



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TERMINOLOGY and ABBREVIATIONS

Terminology

agricultural residues

biomass residues originating from production, harvesting, and processing in agriculture areas

animal bedding

straw or another material on which animals stand in the stable, pigsty and cowshed

animal fodder

straw, hay or another material used for feeding animals

blend

intentionally mixed of different *biofuels or biomass*

biomass residues

biomass originating from well defined side-streams from agricultural, forestry and related industrial operations

cereal crops

annual crops grown with the main purpose to use the seed for food production. EXAMPLE: wheat, rye, barley, oats, maize, etc.

chopped straw

straw which has been cut into small pieces

chunkwood

wood cut with sharp cutting devices in which most of the material has a typical particle length, substantially longer and more coarse than *wood chips.* NOTE: Chunkwood has a typical length of 50 to 150 mm

crop production residues

agricultural residues originating from crop production, harvesting, and processing in farm areas. EXAMPLE: cereals straw, corn stalks, sunflower stalks, etc.

energy crops, fuel crops

woody or herbaceous crops grown specifically for their *fuel* value. NOTE: See also *energy forest trees, energy grass, energy plantation trees.*

energy forest trees; short rotation forestry SRF

woody biomass grown specifically for its *fuel* value in medium to long rotation forestry

energy grass; fuel grass

herbaceous *energy crop*. EXAMPLE: Sugarcane, Miscanthus, Reed canary grass.

fruit biomass

biomass from the parts of a plant which hold seeds. EXAMPLES: kernels, husks, shells, etc.

forest chips

forest wood in the form of *wood chips*

fuel dust; saw dust

pulverised biofuel with a typical *particle size* of 1 to 5 mm. EXAMPLE: (saw dust produced during wood sawing, straw dust – grinded straw)

food processing industry residues

biomass residues originating from the food processing industry. NOTE : It includes among others bone meal, press cake from juice production. EXAMPLE: *(South Europe); olive pomace and pits, cotton ginning residues (in Greece, Spain), also kernels (from peaches, apricots), almonds and nutshells*

green chips

wood chips made of fresh *logging* and *thinning residues,* including branches and tops

herbaceous biomass

biomass from plants that has a non-woody stem and which dies back at the end of the growing season

horticultural residues

biomass residues originating from production, harvesting, and processing in horticulture including greenhouses

logging residues

woody biomass residues which are created during harvest of merchantable timber (i.e. contains of trees tops and branches incl. leaves and needles)

NCV, GCV (MJ/kg) Net calorific value, Gross calorific value of origin biomass (NCV refers to heating value as received during biomass harvesting or extraction)

small wood

fuel wood cut with sharp cutting devices and in which most of the material has a particle length typically 50 to 500 mm. EXAMPLE: *Chunkwood, firewood*.

stem wood; stem wood chips

1. part of tree stem with the branches removed, 2. *wood chips* made of *stem wood*, with or without *bark*

straw

stem of cereals such as wheat, rye, barley, oats

thinning residues; thinning wood, small-size trees

woody biomass residues originating from thinning operations (usually young trees with low diameter of stems <15 cm)

thinning operations

early pre-commercial and commercial thinning operations in young stands; goal of thinning operation is the improvement of species structure of stands and to improve the quality of trees.

whole-tree chips

wood chips made of *whole trees*. EXAMPLE: *Wood chips* containing stems with bark, branches, needles/leaves.

wood chips

chipped *woody biomass* in the form of pieces with a defined *particle size* produced by mechanical treatment with sharp tools such as knives, NOTE 1: wood chips have a sub rectangular shape with a typical length 5 to 50 mm and a low thickness compared to other dimensions

wood processing industry residues; wood industry by-products

woody biomass residues originating from the wood processing as well as the pulp and paper industry. NOTE: See also bark, cork residues, cross-cut ends, edgings, fibre board residues, grinding dust, particle board residues, plywood residues, saw dust, slabs, and wood shavings

wood shavings; cutter shavings

shavings from *woody biomass* created when planning wood

Abbreviations

ACC	EU accession and candidate countries (short-cut ACC-8 countries)
AVHR	Advanced Very High Resolution Radiometer
BtL	Biomass to liquid fuel
CEE	Central and Eastern European Countries (used as CEE-8)
CGMS	Crop Growth Monitoring System
CHP	combined heat & power plants
DEM	Digital Elevation Model
DG AGRI	Agriculture Directorate-General
DHP	district heating plants
d.m. (DM)	dry matter
EDC	EROS Data Center
EFI	European Forest Institute
EGM	EuroGlobalMap
eqv.	equivalent
EROS	Earth Resources Observation Systems
EUSIS	European Soil Information System
FAO	Food and Agriculture Organization
FSU	Former Soviet Union
GIS	Geographical Information System
GPS	Global Positioning System
GVI	Global Vegetation Index
IACS	Integrated Administration and Control System
LC	lingo cellulose
MARS	Monitoring of Agriculture with Remote Sensing
MCYFS	Mars Crop Yield Forecasting System
MODIS	Moderate Resolution Imaging Spectroradiometer
NCV	net caloric value, expressed units s.a.: kJ/kg, MJ/kg, GJ/t, GJ/m^3 etc.
NDVI	Normalized Difference Vegetation Index
NOAA	US National Oceanic and Atmospheric Administration
PELCOM	Pan-European Land Cover Monitoring
R&D	research and development
RES	renewable energy sources
RCG	*Reed Canary Grass*
RDBMS	Relational Database Management Systems
RUE	radiation use efficiency
SABE	Seamless Administrative Boundaries of Europe
sk	standing volume
SMU	Soil Mapping Units
SOTER	Soil and Terrain Resources Information
SRC	short rotation coppice
SRF	short rotation forestry
STU	Soil Typological Units
TCI	Temperature Condition Index
UAA	utilized agricultural area
USGS	US Geological Survey
VCI	Vegetation Condition Index
VHR	Very High Resolution
WUE	water use efficiency
y	year

Units

MJ	(Megajoule) 10^3 joule
PJ	(Petajoule) 10^{15} joule
t	tonne
kt	1000 tonnes
Mt	million tonnes
Mm^3	million m^3
Mha	million ha
dam^3	1000 m^3
cum	1000 m^3
toe	tons of oil equivalent (40,61 GJ)
ktoe	10^3 toe

1. OUTLOOK - BIOMASS RESOURCES AND POTENTIALS IN EU-25

North Europe

In the North, major bio-energy resources are forest residues. Both in Sweden and Finland the forest area exceeds 20 Mha and constitutes a large share of country area, 51% and 67% respectively, while in the EU-15 forests cover 29% of the total area on average. The largest potentials of energy wood are: (i) logging residues from final wood removals and (ii) thinning-wood from the thinning operations. In Sweden the commercial potential[1] of forest residues was estimated at 280 PJ, while current use is 140-160 PJ (Nilsson et al., 2003).

In Finland the potential of wood fuels residues amounts to 10-16 Mm^3 (80-120 PJ) per year (OPET Report, 2002). The wood processing industry by-products (wood waste, sawdust, bark, black liquor) states as large a resource. However they're exploited for energy, wood-boards or pellets production as main market demands. The use of industrial by-products for energy and wood-industry is also growing because the resource use for transportation fuels meets strong competition, the potentials might be limited. Agricultural land is in a minority (2 Mha in Finland and 3 Mha in Sweden). Production of residues (cereals straw, maize residues) is less significant in North EU as the harsh climate does not favour agricultural production. In Sweden cereals straw potential was presented as. 18 PJ (Nilsson et al., 2003). The exception is Denmark, where cereals straw potential was estimated at 6 Mtons (80 PJ) in 1998 and dominated the total biomass potentials. 15% of 6 Mtons was used for energy and 85% was consumed in agriculture (CBT, 1998). Norway poses much less bio-resources.

Eastern Europe (8-CEE countries)

The highest biomass resource potential is expected in the agriculture sector. This is due to a high share of agricultural land in the total area. In Latvia, Lithuania, and Estonia, the agricultural land per capita exceeds 0.8 ha, in Poland it is 0.44 ha (Reiche, 2003). Small grain cereals are the dominant crop, e.g. In Poland the cereal area covers 76% of the total cropland. Cereal straw (from wheat, barley and rye) is the major agricultural residue (of 26-27 Mtons/yr in Poland). Oil-crops straw (rape) production is less than 10% of the total. Great volumes of straw are utilized traditionally in agriculture. Estimates shows that 20-40% of the straw, equivalent to 5-10 Mt could be available for energy or alternative uses. Exploitable forests cover is the highest in Slovenia 51%, Estonia 46% and Latvia 39% respectively. In Poland the forested area covers 8.9 Mha or 28% of the country area, while wood removals equals to 27 Mm^3. Forestry wood and residue potentials was estimated to be maximum 6–8 Mm^3 (40-60 PJ). Currently over half of this (4-5 Mm^3) 30-40 PJ is used as firewood. The major wood-residues are: (i) logging residues *from Pine removals*, (ii) thinning wood *from pre-commercial thinning of 20-70 year old Pine forests*. Wood industry by-products in PL (sawdust, logs, bark) are demanded and utilized mainly by wood industry and for energy production. Not significant volumes are left to consider for the alternative use i.e. transportation fuels production. Forestation increase is intended in all CEE countries.

Western Europe

The primarily biomass in countries i.e. France, Germany, the Netherlands is agricultural residues and forest residues. Agricultural residue production, mainly cereal straw, amounted

[1] commercial potential includes technical, economical and environmental restrictions were taken into account

to about 19 Mton in France and 16 Mton in Germany (Dalianis and Panoutsou, 2001). Roughly 25% of the straw production, respectively 5 Mtons (66 PJ) and 4 Mtons (56 PJ) might be regarded as potential for energy. Forest residues production and wood processing by-products together have roughly the same energy potential as crop residues. The potentials of logging residues and wood from thinning of young forests is significant and is recommended for energy use, while the wood processing industry by-products are mostly utilised now as in other European countries. An opportunity of biomass production is regarded in the energy crops cultivation on the set-aside land, which has been withdrawn from food production, but this is limited to some parts of France and Spain.

UK and Ireland

Both, Ireland and the UK pose a high share of the agricultural land such as permanent pastures used for cattle and sheep grazing. The crop residues production in the UK reaches 10 Mt per year. Cereal straw is a dominant crop residue (Dalianis and Panoutsou, 2003). The woodland area in the UK is 2.7 Mha or 12% of total area. Less important biomass resources are also residues such as mushroom compost and poultry litter. However that biomass is also regarded as residue resource available for local energy production in the UK (McDonnell and Shane, 2004).

Southern Europe

In the southern countries: (Greece, Spain, Portugal and Italy) agricultural residues and fruit process residues are the main biomass resources. Field residues include cereals straw and fruit tree pruning as well as vineyard and olive tree pruning. Dry agricultural residues production amounts to 27 Mt in Spain and 6 Mt in Greece. The cereal residues are a dominant fraction but also the olive-oil field residues are in large quantities (6.4 Mt in Spain and more than 2 Mt in Greece (Dalianis C., Panoutsou C., 2003). Fruit processing industry is well developed, then residue volumes of olive pomace and pits, cotton ginning residues (Greece, Spain), kernels (peaches, apricots, etc) almonds and other nutshells, etc. are produced (Panoutsou, 2004). As for the forestry sector, there are some difficulties in residual harvesting due to sharp inclinations and lack of a forest road infrastructure, however in Spain the forested area is significant and equals 14 Mha. Forestry wood and residues might be seen as second in importance as biomass resources in Southern Europe.

Alpine Region (Switzerland, Austria etc.)

Due to the nature of their mountainous landscape, Austria and Switzerland are countries of large forested lands. In Austria, woodlands make up 40% of the total area (over 3 Mha). Forest residues are the primary biomass resource in Alpine countries. Wood industry by-products are widely used for energy production in the wood processing industry, district heating and for pellets production. Wood industry by-products potentials for transportation fuels are limited. No straw surplus for energy uses exists due to the fact that all straw is used for agricultural purposes.

2. DEFINITIONS AND DATA-BASES

2.1 DEFINITIONS OF BIOMASS POTENTIALS

There is no widely accepted standard terminology for defining renewable energy sources potentials. There are different interpretation of what is ‘potential’ and what resource size is actually achievable. Until now various levels of potentials definitions were used, e.g. theoretical or gross (total biomass resources), technical or net (limited to technical possibilities of extraction or production) and sometimes the term: economic potential is used when economic barriers are assumed to limit biomass resources use. However, despite the confusion with the terminology, certain concepts are presented and recommended to be used in this report and further works in RENEW. At first, biomass potentials were defined at a general level. Then a set of definitions is provided for agricultural residues, forestry residues and energy crops. Additionally, schemes of potentials are provided for each biomass type.

2.1.1. Review of definitions

The total amount of particular energy source, which exists in nature in a given time, is the *total resource*. Fundamentally, at this level we do not take into account any practical constraints, this is the *theoretical potential*. However, we should be aware that the theoretical potential is limited by factors such as the physical or biological barriers that cannot be altered given the current state of science (Smeets et al., 2004). A subset of the theoretical potential is the resource that we can extract *in practice* after various factors are taken into account, for example the technology efficiency, economics of harvesting, etc. Imposing particular constraints will limit the size of the resource potential, thus different definitions include different sets of constraints.

The *technical potential* is the total resource limited by the technology used. Often it is understood as the amount of energy that may be extracted from the resource using the available technology, e.g. the efficiency of the boiler. The term *technical potential* applied for the resource size means the amount of resource that may be produced, harvested or extracted using the currently available technologies, e.g. the harvesting machinery.

All the alternative requirements for the resource must be regarded. For example: from the total straw harvested, we should subtract all the amounts utilized for agricultural purposes such as animal bedding and fodder, etc.

The *economic potential* is the resource on which economic constraints are applied, it means the technical potential that can be provided at economically profitable levels, e.g. at or for less than a given cost. It will include the costs of growing, harvesting, transportation, handling, processing, etc. Contrary to the technical potential, whose size hardly changes, the size of the economic potential can change quickly; for instance changing prices for the competing fossil energies and increasing prices for other primary energy carriers can quickly make the share of the technical potential that so far was unused for economic reasons competitive. Sinking prices for fossil energies on the opposite side lead to the fact that a share of the technical potential already used can become uninteresting from an economic point of view (IE Leipzig, 2004).

If we take into account the ecological criteria, e.g. loss of the biodiversity or soil erosion, we consider the *ecological potential,* but we think that the term *environmental restrictions* fits better. For example for forest residues the environmental restrictions limit the amount of residues that may be removed from forests for energy use. Similarly some part of the straw harvested and other agricultural crop residues must be left in the field for nutrient re-circulation and organic matter restoration. As for energy crops cultivation, the environmental restrictions could relate the area of energy crop plantation (to limit monoculture) or the artificial fertilizers doses, etc.

It's worth being aware that the resource size can change with time for some technologies, particularly for the bio-fuels. Thus, it may be necessary to give a date or even a predicted scenario to accompany the resource size or potential quoted.

After taking into account all the different constraints which limit the resource availability in practice, the resource amount may be defined as the *accessible potential* or *net supply potential* or *available potential.*

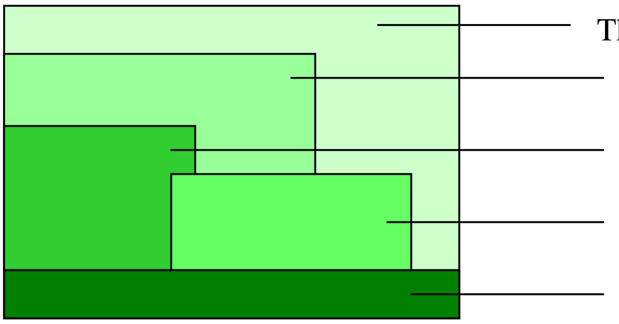


Figure 1: The correlation between different classifications of forest potentials (Smeets et al., 2004)

Note: ENVIRONMENTAL RESTRICTIONS refers to the need to leave some minor elements in certain bio-resources areas (i.e. part of straw shall be left and ploughed in the agriculture fields, part of forestry residues shall be left in forests due to nutrients N, P, K re-circulation in soils in order to balance the biotopes elements losses).

2.1.2. Agricultural residues potentials

Due to the fact that cereal straw is the primary agricultural residue in majority of the European countries, the potential definitions are presented in the case of cereal straw.

Theoretical potential means the total amount of straw produced in a given year. As in many countries there is no statistics on straw, it may be calculated using the straw/grain ratio and statistical data on cereals yields and cereals sown areas. The gross straw/grain ratio relates total straw grown per grain yield. It is different for different cereals.
The theoretical potential is determined by the total straw production and can be calculated according to the formula:

*Total straw production =gross straw/grain ratio * cereal yields (t/ha) * cereals area (ha)*

Technical potential is the amount of straw that is possible to be havest in the field. Straw losses in the field are influenced by the harvesting technology. Additionally, some of the straw harvested, has to be left in the field and ploughed back into the soil for nutrient restoration – this relates the *Ecological potential*. The soil requirements for straw as an organic fertilizer together with the straw losses in the field may reach even 50% of the total straw production (Borjesson, 2004).

A significant part of straw, which is collected, is used for various energy and non-energy purposes. Here are presented common uses of straw (ETSU, 1994) are:

- *Animal feeding*: This process involves the treatment of straw both chemically (alkali) and mechanically (chopping) before being used to produce a feed pellet. Molasses or syrup may be added as a binding agent together with some vitamins.
- *Animal bedding*: Small grain cereals straw is chopped and treated (for fungal spores) and used as a substitute for wood shavings in animal bedding.
- *Crop Protection*: Used, mainly in northern EU regions where low temperatures exist, for the protection of sensitive vegetables (carrots, parsnips, etc.) from frost when they are left in the ground during winter.
- *Composting* (mushrooms): Wheat straw is used to provide a composted medium for the mushroom production industry.
- *Energy use:* straw as a fuel for heat and electricity production
- *Others* (paper pulping, exportation, horticulture use, use as building material etc.).

*A*fter taking into account the straw requirements for soil and agricultural purposes, export and current energy and industrial uses the straw surplus is left. This is the NET *technical potential of straw for energy use*. However, it may be divided between competitive demands: heat production, electricity generation, transportation bio-fuels (BtL) production as well as other industrial production.

The technical potential for energy use may be limited by economic constraints: e.g. straw resources are found in remote and isolated regions; the fields are very small or are highly dispersed, thus the harvesting-transportation cost may be very high (Dalianis and Panoutsou, 2003). These constraints determine the *economic potential* of straw available for energy purposes.

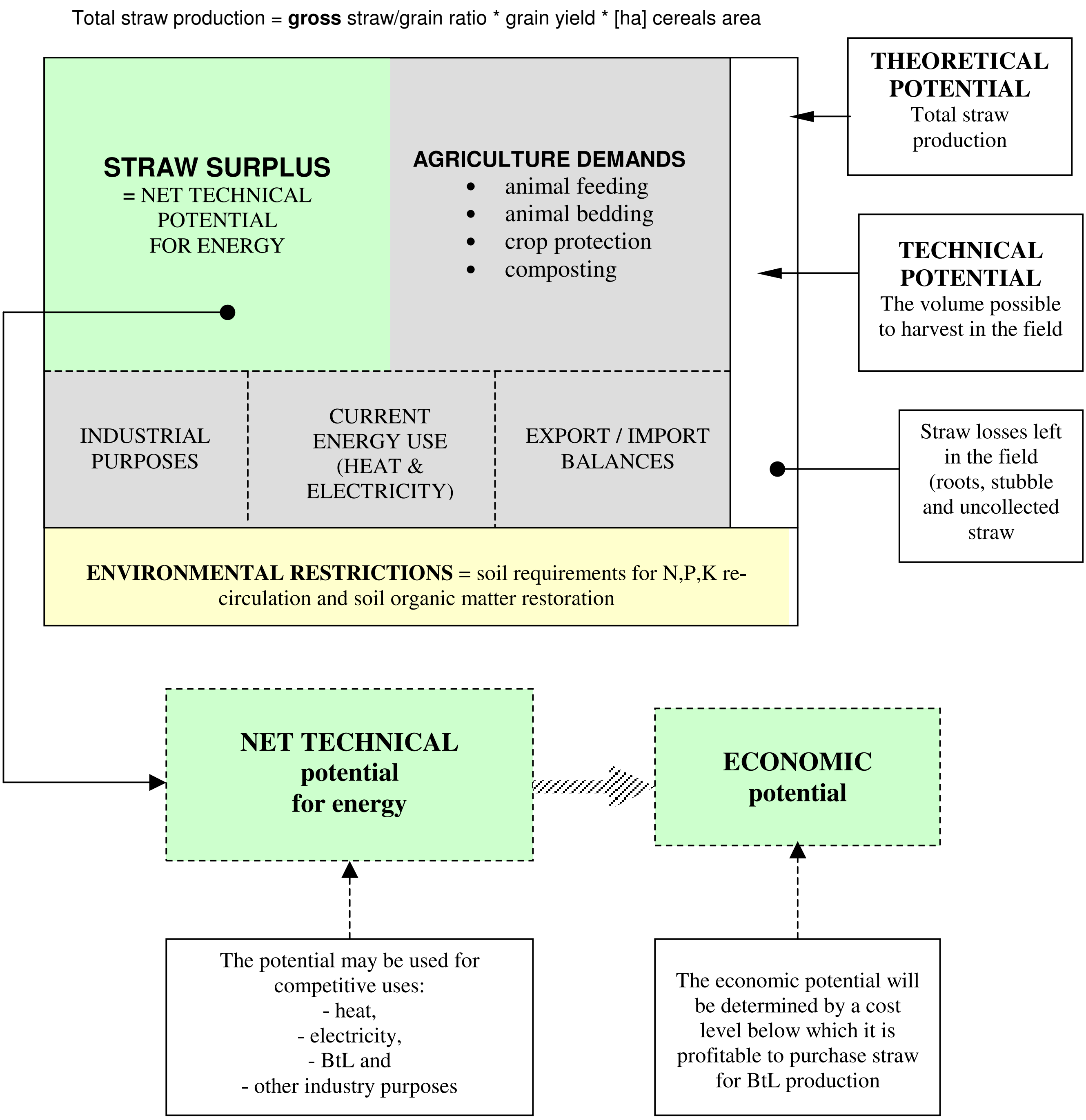


Figure 2: The straw potentials scheme and its relationship to environmental restrictions and market demands

2.1.3. Definitions of forestry potentials

Many systems of methodology of the wood forestry potential assessment and definitions have been developed. Below there're presented some selected definitions from regional and national studies.

Methodology 1 (Rozanski and Jablonski, 2003)
The total potential which can be utilised for energy purposes (in Poland) was defined as presently harvested fuel wood and actually not utilised harvesting residues. The wood from intermediate cuttings is not taken into consideration because of the small concentration per land unit and lack of a proper infrastructure. In order to harvest a residues assessment the trials fields was established and the measurements of particular fractions of trees were done. The total theoretical potential of harvesting residues was calculated as the product of average mass of harvesting residues from the tree, the number of trees per unit area and the area on which the final cuttings have been done.

Methodology 2 (Hakkila , 2003)
The first step was a theoretical potential estimation including:

- residues from integrated operations (harvesting of industrial raw material and fuel)
- stump wood from integrated operations
- separate fuel wood operations

Then it was estimated what proportion of the theoretical biomass reserve is actually harvestable; it is the technically harvestable biomass potential estimated as 22-35 % of the theoretical potential and it depends on the price development, costs limit, labour supply, and environmental factors, etc.

Methodology 3 (Baltrusaitis and Andersson, 2000)
Wood fuels are defined as all bio-fuels originating from trees and consisting of wood, bark, needles or leaves. Wood fuel includes: forest fuel, fuel from coppice and recycled fuel. The part of forest fuel that comes directly from the forest (fire wood, logging residues etc.) is defined as primarily forest fuel, which includes:

- logging residues
- stem wood from final cuttings, thinning, etc.
- wood without industrial demand or use

Methodology 4 (CLIP, nr 8/1998)
The available wood fuel potential was calculated as annual growth of standing tree stocks excluding:

- the share of biomass left on the ground for soil regeneration
- wood industry products
- actual fuel wood consumption
- to which was added untapped waste wood (old packaging etc.)

Methodology 5 (Smeets et al., 2004)

- Theoretical potential – the total growth from all forest areas
- Technical potential – potential from areas classified as physically accessible.
- Economic potential – the growth of commercial species on forest areas classified as available for supply. Growth data are based on the gross annual increment of

commercial species (GAI). Note that the term commercial refers to the suitability of species for the present international timber market. Since most of the forest biomass is suitable for bio-energy production, using this definition implies that the economic potential for bio-energy is underestimated.

- Ecological potential – the total growth from forests classified or disturbed, thereby not disturbing old growth forests.

Discussion and methodology used in RENEW potentials estimates

We used the following method after reviewing literature and regional experiences presented by WP5.1 team partners. We assumed that forestry potentials includes fractions of:

(i) logging residues (tops and branches), and
(ii) thinning wood (small-size trees) from pre-commercial thinning of young forests and clear-cuttings.

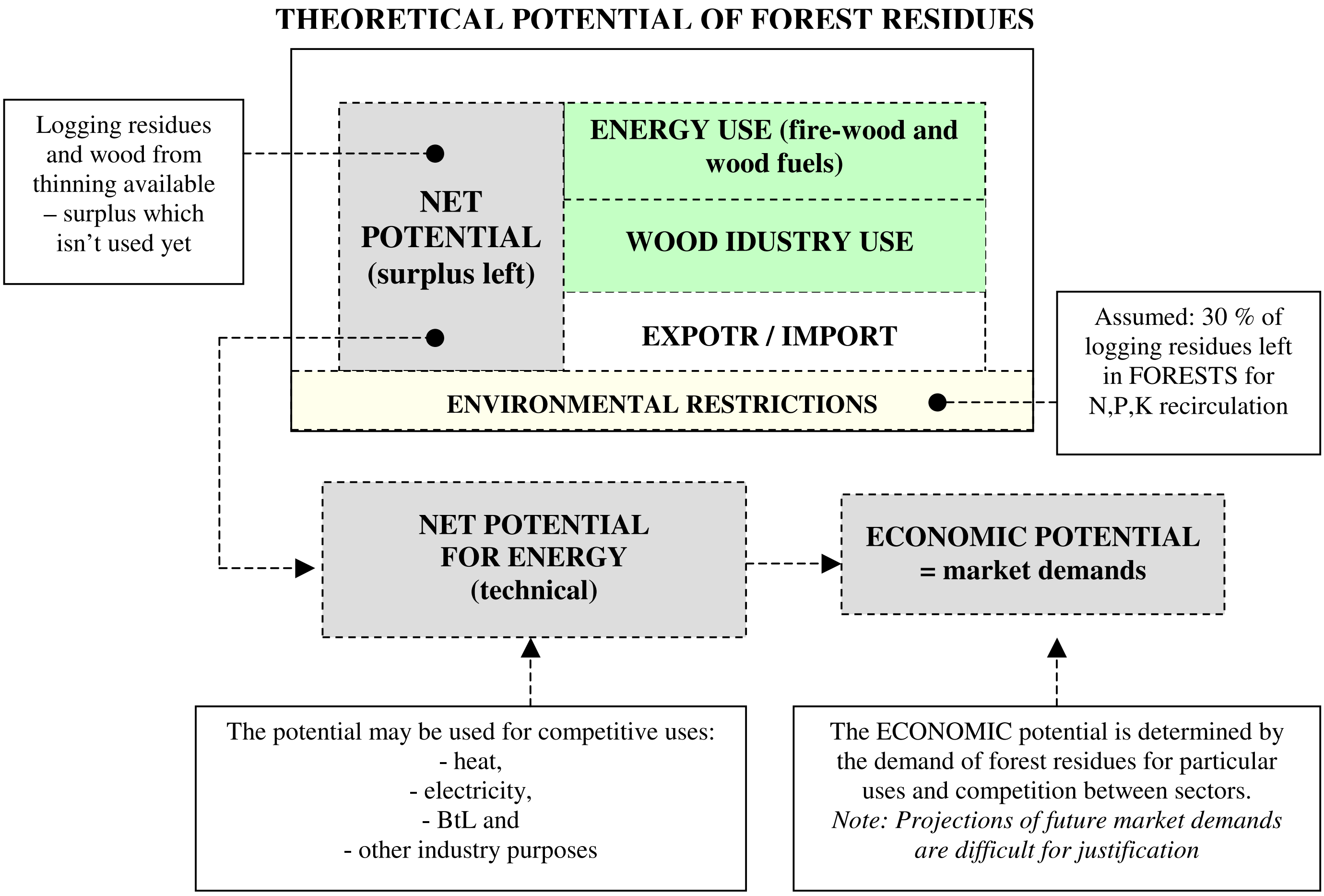


Figure 3: Forest residues potentials scheme

Root and Stump wood from wood felling was not involved in consideration after initial discussion. Also hypothetical INCREASE OF TIMBER WOOD REMOVALS for energy/BtL use (up to the level of 100% of the net annual wood increment in exploitable forests) was not considered as forestry potentials. Extending wood removals from European forests strongly depends on many factors, i.e. wood-industry demands, national forestry policies and environmental restrictions. This item should be resolved at a later stage of project.

The Theoretical (gross) potential was defined as the current production of forest residues during the felling. As the Net surplus Potential – potential still available to use - it was defined as the difference between the theoretical potential minus the current utilisation for energy and industry purposes. The assumption that 30% of logging residues should be left in the forest was made due to environmental restrictions (circulation of nutrients N, P, K in the forest soils) based on the research provided in North EU (i.e. in Sweden and Finland). The Net Potential and its use depend on future market demands and economic competition between particular sectors. Wood residues utilisation increase in the future can be driven by: wood industry (particle boards production), heat and electricity production, building materials or for BtL production.

2.1.4. Energy Crops potentials

Methodology 1 Potential of energy crops in contaminated areas (Goor et al., 2000)

The potentials in regional scale was estimated with the use of geographical approach. In the area of Ukrainian *Polissky* district (1350 km^2 around Chernobyl) it was provided the assessment of locations and soils suitability for SRC willow cultivation in contaminated area. Potentials of energy crops yields were calculated together with co-efficient of possible transfer of radioceasium (TF's) from soils to SRC wood. This corresponded to estimates of specific vegetation factor of SRC willow ($Bq*kg^{-1}$) and soil contaminations ($Bq*m^{-2}$). The geographical method started with creation of soil map with 5 soils classes. Then also map with 5 classes of land cover (incl. agriculture lands location) was prepared and map with classes of soil contamination with ^{137}Cs in whole district. Yields of energy crops were from in-situ field trials located on typical sandy or peaty soils in the district. Yields varied 4 – 17 t d.m. per $ha*y^{-1}$. Method and data processing included the use of vegetation - land cover map to isolate arable lands and overlay soil types on arable land areas. As 2'nd step map of SRC yields areas was created, by multiplying soil types with yields value. Finally yields values map was overlaid with map of ^{127}Cs contamination and then weighted mean of ^{127}Cs was calculated for each arable land location. Results of the study present five selected soils types, which are clustered into three main groups, two of which (covering 48% area) can usefully be used for SRC. Energy crops potential on the total district area was estimated 280 ktons d.m. per y^{-1}.

Methodology 2 Agriculture land suitability potentials for energy crops in CEE countries (Velthuizen, 2003)

In this study the agro-ecological zoning approach was used to select most-suitable agriculture land areas for energy crops and cereals in central and north EU. For the land productivity values selection, Pan-European geo-databases were used on: climate, soils type, elevation and slopes and current land-use. The climate parameters i.e. temperature, rain precipitation and length of vegetation period and dry-ness index were used for selection of different agro-climatic zones. Then respective layers were prepared: elevation of agriculture lands, agriculture land slopes classification and soils types on agriculture lands. Then also assumptions of 3 levels of farming inputs were set: high, medium and low. For example high-level input assumption included high-yielding varieties, crop production mechanization with low labour and optimum applications of nutrients, pesticides and weeds control.

Regarding energy crops parameters it was taken into account crop characteristics (i.e. crop cycle, water requirements and moisture stress reduction etc.), conversion factors (i.e. harvest index, extractions rate etc.) and environmental requirements (i.e. thermal climate, temperature profile, growing period, soil and terrain conditions etc.). SRC Willow, poplar, alder and ash were used, as energy crops indicators. For both cereals and LC energy crops climate parameters requirements were defined. Also optimal conditions of soils requirements and terrain-slopes ratios and rain-fed plants parameters were taken into account. Finally as a result it is presented map layout of few CEE countries (incl. Poland). Selected agricultural lands are clustered for representing area suitability for certain crops. For example map of Poland's agriculture areas was clustered into 6 classes (0-85 points marked) representing areas for SRC willow or other crops from not suitable, through marginal and moderate until high-yielding. Two lands-classes, most suitable for cereals were selected in certain areas in parallel also.

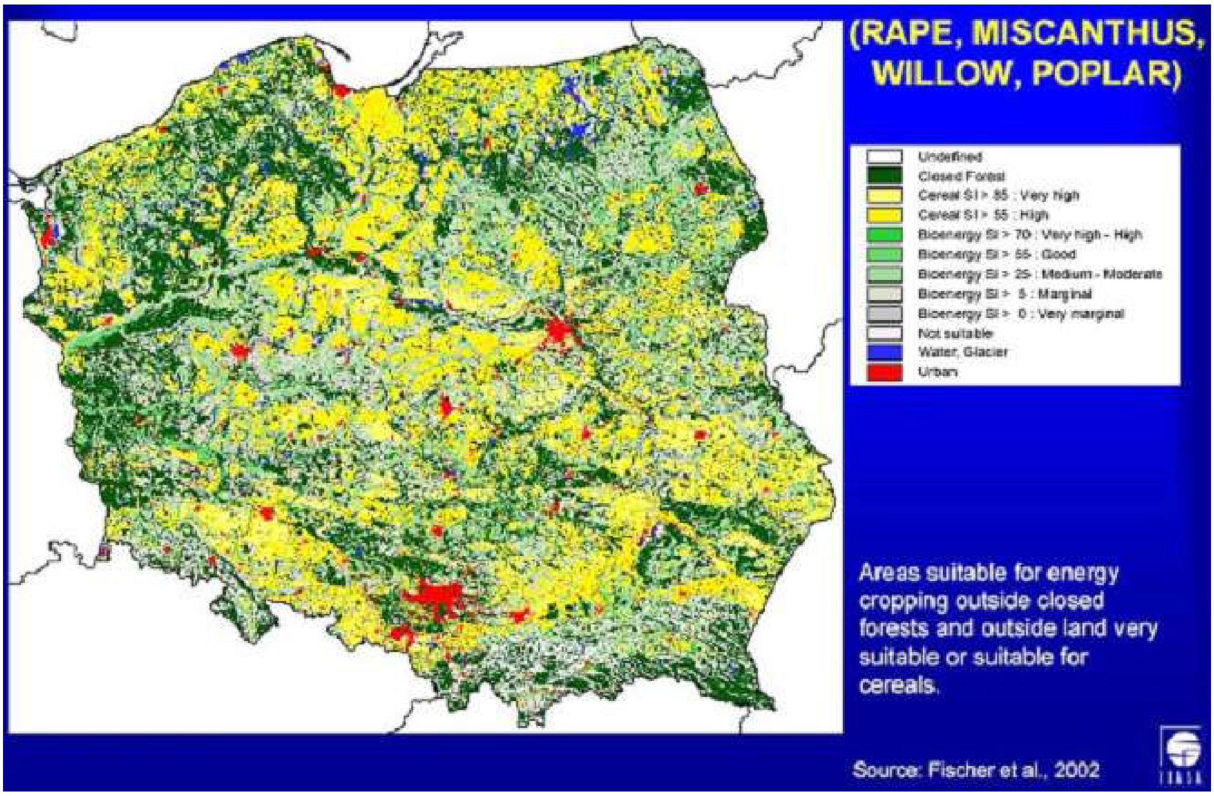


Figure 4: Results from geographical analysis of land suitability for LC energy crop cultivation in Poland (Velthuizen, 2003)

Methodology 3 Geographical potentials of energy crops (Hoogwijk et al., 2004)

In this study 3 land categories were defined as suitable for energy crops: (i) set-aside lands, low-productive lands and "rest lands" i.e. remaining no-productive lands (savannah, shrub land and grassland/steppes). The *Geographical potential* of energy crops is defined as the total amount of primary biomass from energy crops as land area available for the production of biomass for energy, calculated in the following way (Hoogwijk et al., 2004).

$$G_r = \sum_{i=1}^{n} A_i \cdot a_i \cdot Y_i \cdot MF$$

G_r is the geographical potential of biomass from energy crops in region r (EJ y^{-1});

A_i is the area in grid cell i (km^2); a_i is the land-claim exclusion factor for energy crop production in grid cell i (-) which accounts for competing land-use options;
Y_i the harvested rain fed yield of energy crops in grid cell i calculated by IMAGE 2.2 (GJ ha^{-1} y^{-1})
MF is the management factor representing the development of the management and technology (-).

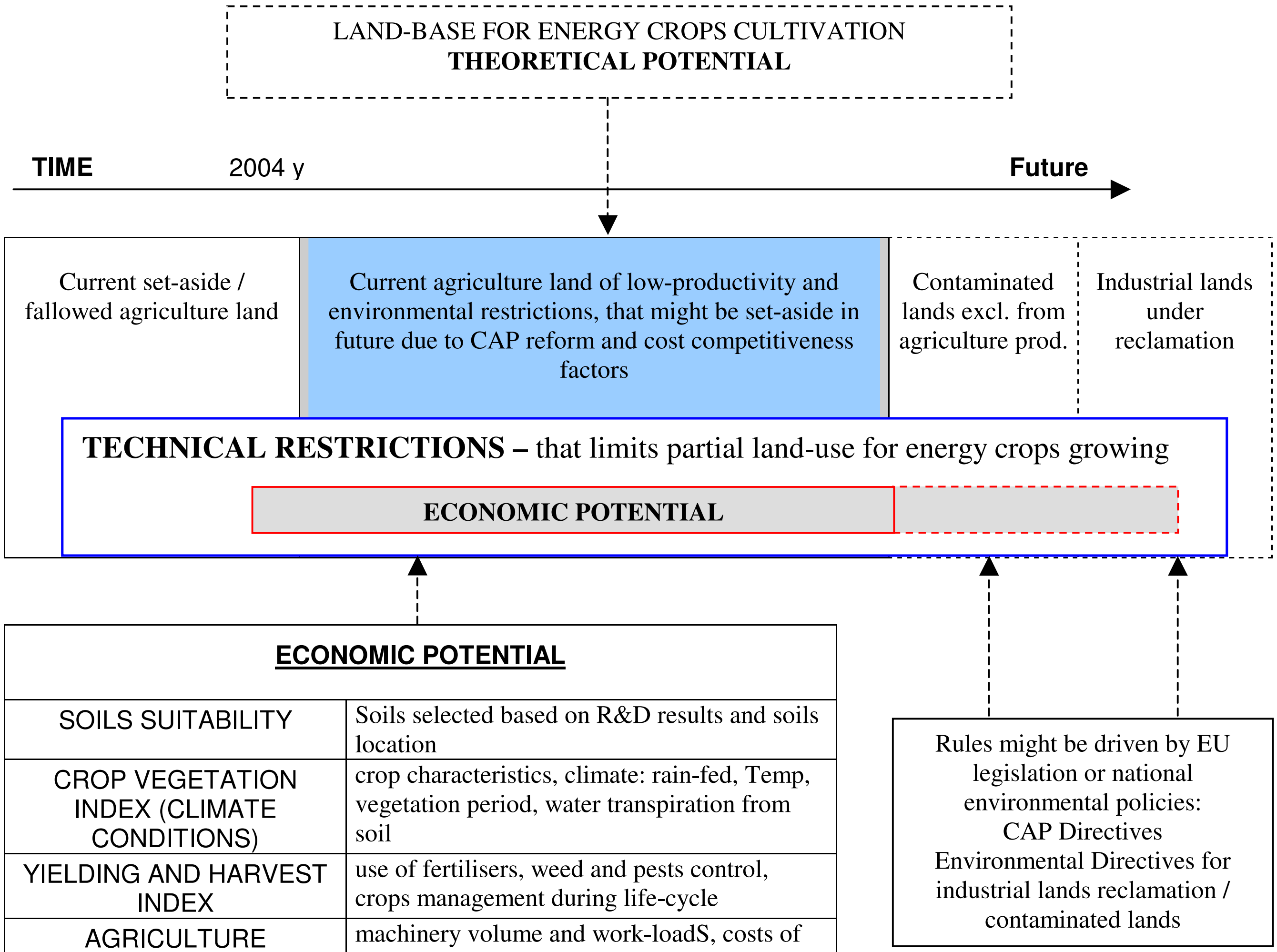
The study included woody energy crops planted in short rotation as base energy crops. For moderate climates typical crops were willow and poplar, for more tropical climates – eucalyptus was assumed. The assumption was made that the production of an energy crop should not effect food and forestry production, nature reserves, biodiversity and animal grazing. Furthermore tundra area is excluded as it is considered to be unsuitable for energy crop production. Desert areas were not excluded, but the land remains zero. The results of the geographical potential was estimated using 4 scenarios: A_1, A_2, B_1,B_2 based on storylines published by the IPCC and integrated with the IMAGE 2.2 model. Energy crops productivity was a function of environmental conditions (soils quality, water balance, growing season, climate).

Discussion on energy crops potentials and factors influencing potentials

Theoretical (gross-sown) potential of energy crops may relate to different lands definitions available for crops production (as a total energy content of the energy crops grown yields on the agriculture land and other lands) i.e.:

a. the land which is currently withdrawn from the food production and may be used for alternative crops (set-aside land, fallowed land, unproductive and unused land, contaminated land, lands under reclamation etc.)
b. the agriculture land or arable land which would be released from food production, assuming that i.e. a certain part of the lands (i.e. 0.24 ha per capita) is sufficient for food production to feed the population in a certain area. Then the rest land could be hypothetically used for any agriculture production incl. energy crops.

Net-yielding potential relates to energy crops produced on the lands suitable for certain energy crops under respective environmental conditions in region (i.e. climate, temperature, growing season, precipitation etc.) Net-yielding potential differs in comparison to theoretical values calculated before cultivation. Lower values are met due to the poor climate conditions, the fact that there is not average field preparation, fertilization, weed control or clones/seeds were of low quality and that affected yields. But opposite also higher net-yielding values would result from better than average climate or agriculture conditions.



ECONOMIC POTENTIAL	
SOILS SUITABILITY	Soils selected based on R&D results and soils location
CROP VEGETATION INDEX (CLIMATE CONDITIONS)	crop characteristics, climate: rain-fed, Temp, vegetation period, water transpiration from soil
YIELDING AND HARVEST INDEX	use of fertilisers, weed and pests control, crops management during life-cycle
AGRICULTURE INFRASTRUCTURE	machinery volume and work-loadS, costs of agriculture operations in region
ECONOMICAL FACTORS	subsidies for establishment / feed-in tariffs for product purchase
SOCIAL FACTORS	human resources in agriculture production, farmers preferences

Figure 5: Energy crops potential relation scheme

Theoretical potentials of energy crops depend on agriculture lands available in certain region, crop species and varieties, environmental conditions and soils types and productivity. But when considering economical potential it depends on: (i) agriculture infrastructure, (ii) social factors and (iii) market demands driven by costs production and purchase. While social factors are considered it shall be included human resources in certain region but also farmer's preferences indicators. While agriculture infrastructure is considered, energy crops production potentials may relate to agriculture machines volumes in certain region and it's workload during the season. Otherwise additional necessary equipment is affecting investment costs. While market-development factors are considered, any subsidies for energy-crops investments or feed-in tariffs for product purchase shall be included.

It is difficult to define relation between factors influencing estimates of energy crops potentials, due to fact that any productive land could be used for it's growing under market competition. Definition of the energy crops potentials is one of the main challenges in Work Package 5.1 during the project in 2'nd year - 2005.

2.2 DATA-BASES AND STATISTICS

The following chapter contains an overview of European statistical databases. Only databases related to agriculture and forestry statistics are presented as they are considered to be useful for further calculations in the project. The overview includes EUROSTAT databases, FAOSTAT and TBFRA-2000 database.

EUROSTAT

EUROSTAT database contains statistics for all European countries. Data are presented separately for each country as well as they are aggregated in country groups such as EU (15), EU (25), Euro-zone (12). Data on Agriculture Forestry and Fishery include 11 domains.

Economic accounts for agriculture and forestry	Agricultural prices and prices indices
Structure of agricultural holdings	Agricultural products
Agriculture information system	Database on orchards
Animal feed	Database on viticulture
Fishery statistics	Forestry statistics (1992-2000)

Some statistics are freely obtainable on-line, but they contain a very limited number of data. Generally the statistics must be purchased in EUROSTAT data shops. The price for the data depends on the amount of data and the number of tables. Min. price is EUR 15 (excl. tax).

NEW CRONOS

The NEW CRONOS is based on the Eurostat. New Cronos includes data on the national level from all the EU-15 countries. The following domains contain data both for the EU-15 as well as for the New Member States (former ACC):

- Economic accounts,
- Structure of agricultural holdings,
- Agricultural products,
- and Agricultural prices and indices

Unfortunately the latest data in the data base main indicators are from 1997. The statistics are presented at the national level, however some tables contain data on the regional level (NUTS-2). On the level of NUTS-3 there are no figures. The variables on agricultural production and land use belong to functions such as the size of the farm but not to different crops. There are also no figures for yield.

REGIO

The REGIO database is a database of the Statistical Office of the European Communities (Eurostat). REGIO provides data on NUTS level 2. For former candidate countries, the territorial units are not NUTS, but "statistical regions" (SRE). While the data for Member States in general is available at NUTS level 2, for Estonia, Latvia, Lithuania and Slovenia it is often at level 3 of SRE, given that for these countries no level 2 is defined. The REGIO database contains several variables such as: agricultural accounts, structure of agricultural holdings, land use, some agricultural production, etc. Crop production data includes areas harvested (1000 ha), production (1000 t) and yields (t/ha) of different types of crops. The data on land use, which may be especially useful for biomass resources and potential assessment, contains the following tables: Total area, Wooded area, Utilized agricultural area, Kitchen gardens, Permanent grassland, Permanent crops, Vineyards, Olive plantations, Arable land, Green fodder on arable land, Fallow land.

FAOSTAT agriculture database
http://apps.fao.org/faostat/collections?version=ext&hasbulk=0

The FAO Statistical Database (FAOSTAT) is an on-line multilingual database currently containing over 1 million time-series records from over 210 countries and territories covering statistics on agriculture, nutrition, fisheries, forestry, food aid, land use and population.

Data for all countries are provided only on a country level. Data are also aggregated to a country groups, e.g. Europe, European Union (15), European Union (25), etc. The statistics are available over a period of several years. The database provide data on:

Agricultural Production	Land Use	Fertilizer and Pesticides
Trade	Forest Products	Agricultural Machinery
Food Balance Sheets	Fishery Products	Food Aid Shipments
Producer Prices	Population	Exports by Destination
Forestry Trade Flow	Codex Alimentarius Food Quality Control	

The domain agricultural production includes the category 'crops primary', in which statistics on numerous crops are presented. Data are also aggregated in crops groups, e.g. cereals, citrus fruit, fibre crops, oil crops, etc. For each crop we can find data on the area harvested, yields, production and seed for sowing or planting.

For each item included in the database there is a definition provided, e.g. definitions of different crop species, land use type, population type, etc.

Land use data are divided into the following subcategories: total land, land area, agricultural area, arable & permanent crops, arable land, permanent crops, permanent pastures, forest and woodland, all other land, non arable & non permanent. All the categories are explained. The areas are given in 1000 ha.

However, there may be some complications when using FAO and EUROSTAT data to create one database. They do not use completely the same classification for agricultural crop products, e.g. tropical (exotic) products are included in FAO cereals classification, and are not mentioned in the EUROSTAT classification.

FAOSTAT Forestry
http://faostat.fao.org/faostat/collections?subset=forestry

The FAO Statistical Database (FAOSTAT) is an online multilingual database currently containing over one million time-series records from over 210 countries and territories covering statistics on agriculture, nutrition, fisheries, forestry, food aid, land use and population. FAOSTAT Forestry provides annual production and trade estimates for numerous

forest products, primarily wood products such as: (i) timber, (ii) wood panels, (iii) pulp and paper.
For many forest products, historical data are available from 1961. These estimates are provided by countries through an annual survey conducted by FAO in partnership with the International Tropical Timber Organization, the UN Economic Commission for Europe and EUROSTAT (the Council for European Statistics). In the cases where countries have not provided information through the questionnaire, FAO estimates annual production based on trade journal reports, statistical yearbooks or other sources. Where data are unavailable, FAO repeats historical figures until new information is found. The definitions used in database were grounded on "Classification and definitions on forest products" FAO, Rome 1982. Since the 1990's trade elements of Forest Products database "Standard international trade classification (SITC)", Rev. 3 has been adopted.

TBFRA-2000
http://www.unece.org/trade/timber/fra/welcome.htm

The Temperate and Boreal Forest Resources assessment (TBFRA-2000) is an electronic database in Access 97 and 2000, as well as the Main report published and distributed by the UNECE/FAO. TBFRA-2000 contains data, by country, on all aspects of the forests of North America, Europe, CIS. Australia, New Zealand and Japan. It is a contribution to the global Forest Resource Assessment 2000 (FRA) led by FAO. TBFRA data will be included in the FRA data set to provide a single global source of data on the world's forests, with comparable terms and definitions for all countries. The data were supplied by national correspondents, adjusted to conform to international definitions, and validated by ECE/FAO Geneva.
The work was guided by a team of specialists and the Joint FAO/ECE Working Party on Forest Economics and Statistics. Contents of TBFRA 2000:

- 81 main tables of data by country
- Notes and comments on the data, provided by national correspondents (sources, inventory concepts, methods of adjustment to international definitions etc.)
- Six major chapters by leading experts in the field, presenting the broad picture and analysing the major issues
- A special chapter on the reliability, comparability and precision of the data

Biodiversity and the environment protection functions of the forests are analysed in a special TBFRA chapter, but generalisations at the region level are not possible.

3. METHODOLOGIES

3.1 BASE METHOD

To assess the biomass resources for the needs of RENEW project it was used the methodology from a study ***Assessment of the potential biomass supply in Europe using a resource-focusing approach*** (Ericsson and Nilsson, 2004), farther called as a BASE method. This study provides the assessment of the biomass potential supply on the national level and within a European geographical scope based on data from 2000 year. This was the main reason to chose the methodology for RENEW biomass potential calculations. Base method applies resources focussing approach that focuses on the total biomass resources data. In RENEW the competition between different uses of them is described and discussed (i.e. demands for straw in agriculture, use and demands of forestry residues for energy or wood industry). Majority of data about resources are based on the pan-European statistical databases: FAOSTAT – data on agriculture land use, agriculture production and TFBRA – data on forestry and forestry industries. Data from FAOSTAT and TFBRA were verified by WP5.1 partners by the use of national statistics and literature.

In the BASE method a biomass potential volumes was calculated using fixed ratios of agriculture, forestry and wood industry residues generations, which resulted in some kind of a theoretical numbers. In RENEW works a step foreword was made to estimate the realistic-market amounts of biomass available for energy use regarding all current competitive uses. This was done by the investigation of different national studies and statistics in order to verify the assumptions of the Base method. Specific ratios of residues generation were obtained as well as crucial comments on specific countries conditions affecting the biomass supply for energy. Energy crops opportunities were applied in two ways – current scenario and future one over 2020y. For current scenario we assumed energy crops cultivation on 100% set-aside lands, for future scenario we assumed decrease of agriculture area for food production due to intensification of food production in agriculture.

RENEW works resulted with a guidance for detailed biomass potential assessment methodology of a European scope to meet specific regional and countries conditions.

In the (Ericsson & Nilsson, 2004) study the biomass assessments were performed on the national level and included EU-15, ten of the EU candidate countries (CC10), plus Belarus and the Ukraine (FSU: Former Soviet Union). The intention was to map the distribution of the potential biomass supply in Europe, both in absolute numbers (PJ) and relative numbers (GJ/capita).

The BASE method for RENEW was based on the (Ericsson & Nilsson, 2004) study. Originally, in the study the assessments of biomass potential were carried out for three main scenarios, however for the needs of RENEW we focus only on the short-term and long-term scenarios.

- For the calculation of agricultural crop residues and forestry and wood industry residues the short-term scenario (10-20 years from today), is applied.
- For energy crop the long term scenario (>40), is applied as large-scale energy crops cultivation is considered to be the matter of the future.

To see the scenarios' assumptions applied for the RENEW BASE method look at the *Table 1.*

Table 1 Explanations of the assumptions applied for the RENEW-D5.1.1 potentials revision.

Denomination	Comment
Forest residues FR1	Tonne residues per tonne stem wood: 0.15 (coniferous) and 0.1 (deciduous)
Forest industry by-products FB	20% of industrial round wood processing assumed as by-products available for energy
Crop residues CR1	Based on the average cereal crop yields (1998-2002), the residue generation rate is 1.3 tonne straw / tonne grain produced and 1 tonne corn residues / tonne corn. Regarding the use of straw in animal production as bedding in livestock housing systems, 0.22 tonne straw per tonne cereal, 0,25 tonne maize residue/t grain becomes available for energy-use.
Energy crops scenarios EC3	EC3 scenario is a long-term scenario (>2040yr), assumptions are following: e-crops on agricultural land that is not required for food production, which claims 0.24 ha/capita; yields 20% higher to EC2 due to effect of learning of agriculture practices of energy crops cultivation

Figures 6-8 present the areas of agricultural and forestry resources as well as land resources, which are the base for the biomass potential calculations and assessment.
Figure 6 presents the areas growing permanents crops, maize and cereals.

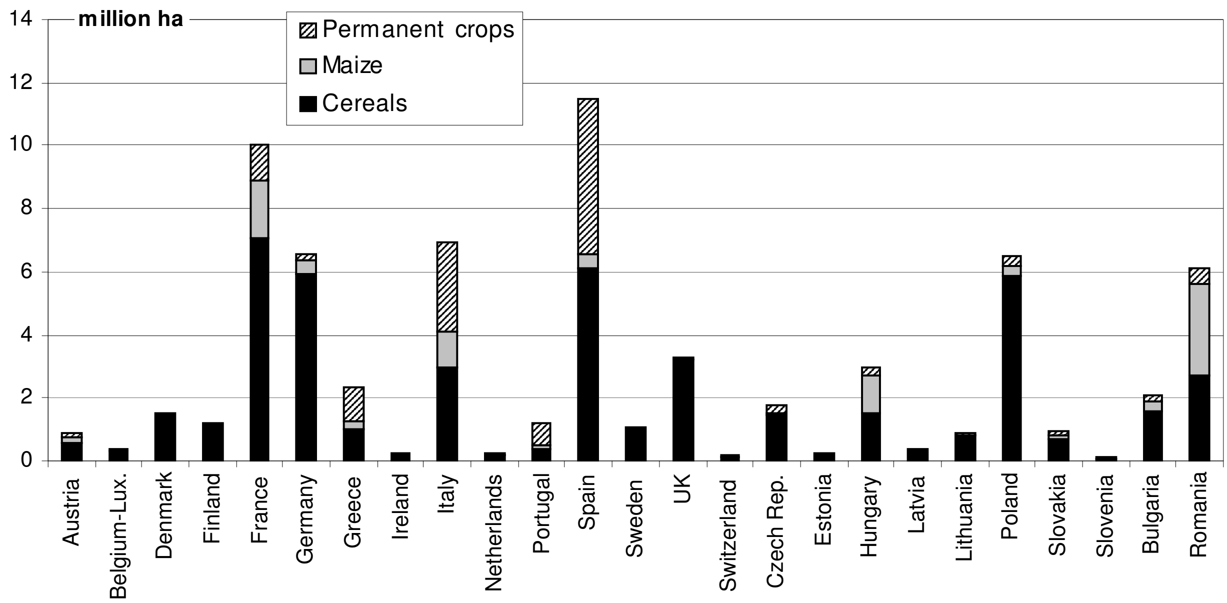


Figure 6: The cereals (wheat, barley, oats and rye), maize and permanent crops (vine, fruit trees, olives) land (FAO-Agriculture, 2000)

Obviously geographically large countries, such as France, Spain and Poland, have the largest absolute cereals areas. In such countries as Spain, Italy, Greece, Portugal and France permanent crops have a significant share of agricultural land. They include vines, olives and fruit trees.

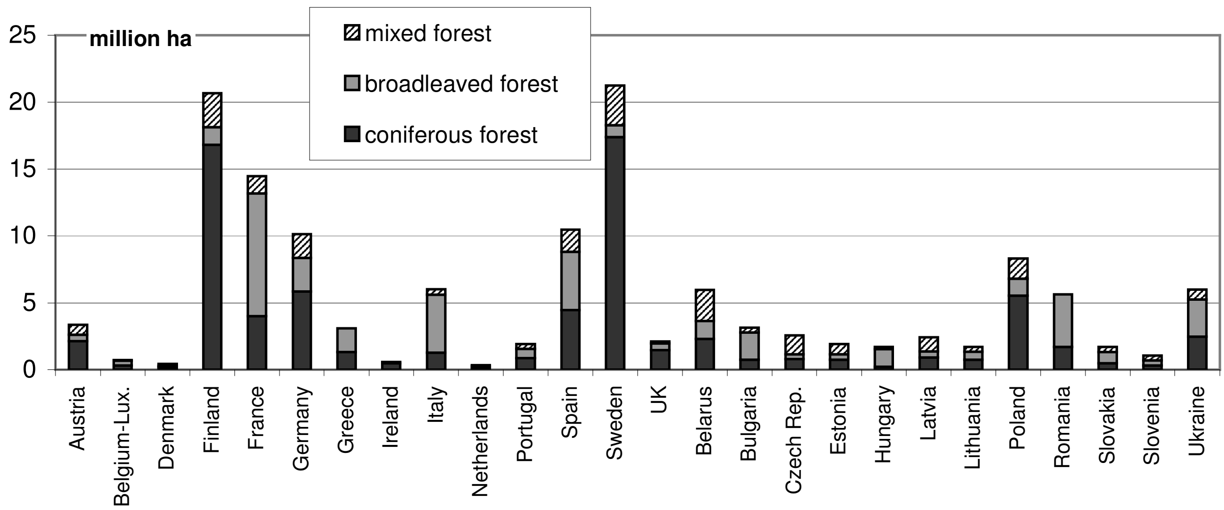


Figure 7: Area of exploitable forests by forest types including: coniferous, broadleaved, mixed forests (TBFRA; 1996)

The Figure 7 presents data on exploitable forestry areas at the national level, which refers to forestry areas with no special restrictions in the forestry management system. Exploitable forestry areas do not include: (i) national parks and (ii) special areas protected due to environmental restrictions where management system and wood felling is not provided according to typical practices.

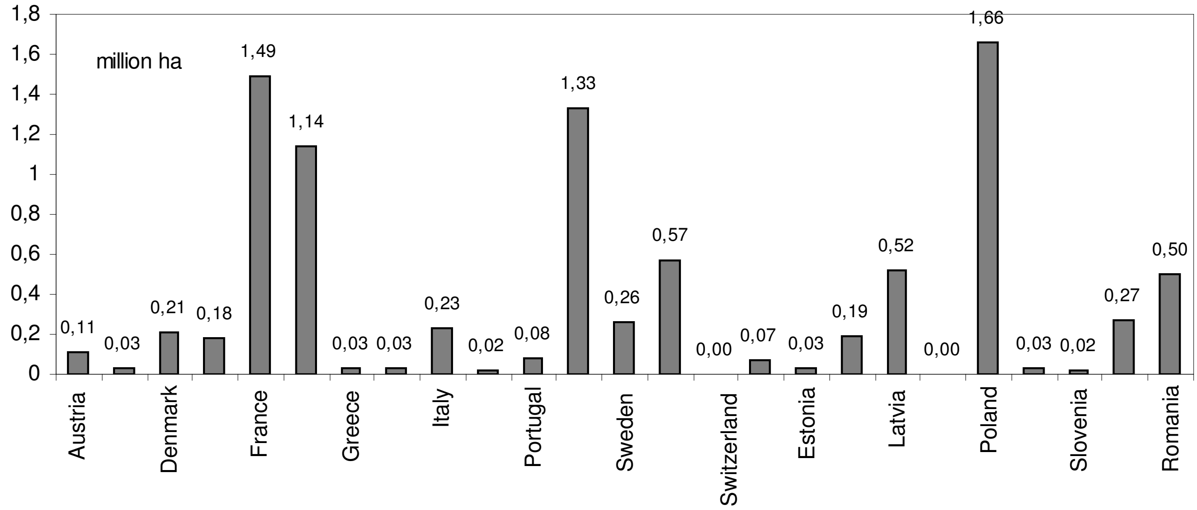


Figure 8: Set-aside land in Europe (FAO-Agriculture, 2000)

Figure 8 presents the current state (based on data from 2000 yr) of set-aside arable lands in EU-25. Geographically large countries respectively FR, GER, PL, SP, UK have each the highest surplus agricultural land (above 0.5 - 1 Mha per country) which could be potentially used for any alternative agricultural production. The total amount of set-aside land equalled ca. 8.2 Mha in EU-25 in the year 2000. We assumed in the study for the potentials calculations, that 100% of the set-aside land volume is suitable for energy crops cultivation. Other lands i.e. contaminated lands, or industrial lands under reclamation were excluded from consideration at this stage.

However, in the future intensification of the agricultural production is expected due to more intensive use of fertilisers, improvement of raw sawing grains and also a better agricultural management scheme in East Europe. It was assumed in BASE METHOD that the requirement of 0.24 ha of agricultural land per capita will be sufficient for food production in the 2020-2040y perspective. Current indicators in the EU-25 countries vary due to population density and agriculture production capacities. For example it varies between 0.41 – 0.93 ha/capita for food production in East-EU ACC countries, respectively in Poland 0.44 and in Lithuania 0.93 ha/capita. In Western countries with very intensive agriculture production and better investment and management capacities it varies 0.2 – 0.5 ha/capita, respectively 0.20 in Germany, 0.28 in UK and 0.33 ha/capita in Sweden.

Then *Figure 9* presents the hypothetical set-aside arable lands distribution in a longer-term perspective, when it is assumed 0.24 ha/capita will be sufficient for food production. Then major surplus agriculture land might be available in countries i.e. France, Spain, Poland and FSU (Belarus, Ukraine), which is not included in the graph. Some results for countries i.e. Germany, Bel-Lux, Netherlands, Switzerland are at "0", due to the high-population density, and resulting from the low rate of agricultural land per capita (0.2 ha/capita in Germany).

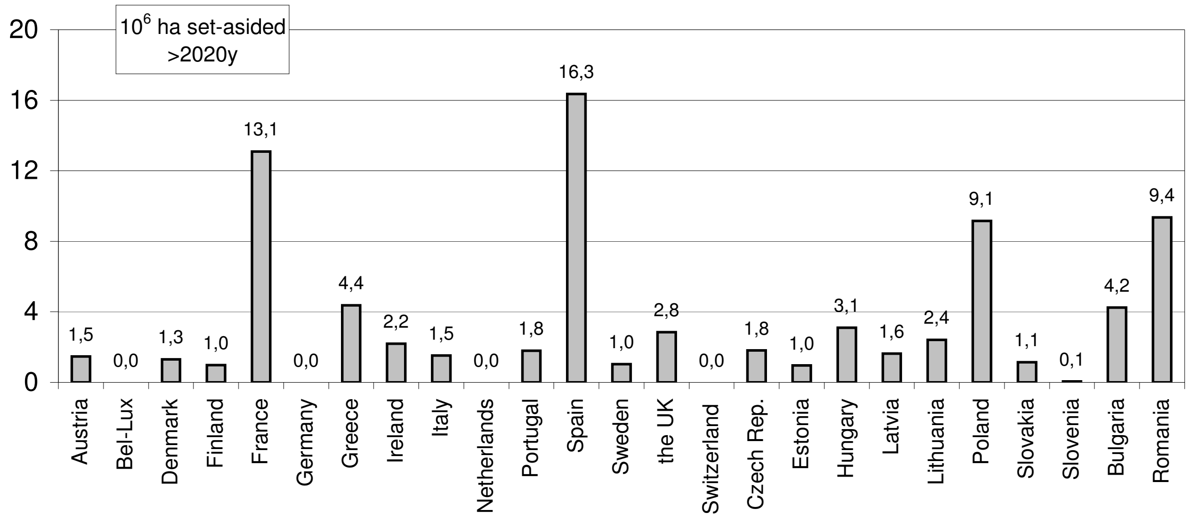


Figure 9: Agricultural land that is not required for food production in long-term perspective (over 2020 y), which claims 0.24 ha/capita demands sufficient for food production, (own estimates based on data from FAO-Agriculture, 2000)

The assumption for the future seems to be discussable, respectively due to difficulties in predictions of food-production markets and food-products flows in the future, i.e. the following factors may influence food productions flows in Europe in 20-40 years perspective: (i) increased export of food production from EU, (ii) increased import of food from Asia, Africa to EU, (iii) any national policies or restrictions, (iv) Common Agriculture Policy rules, (iv) environmental directives as well as (v) the consumers' preferences for food consumption. We think that in further works on methodologies development for energy crops potentials assessment, respective discussion is needed in WP5. One team should draw possible future food production flows in each region/country in the EU. Regional and national differences in arable land changes and food export/import balances shall be estimated as the base for more precise hypothetical increase of set-aside surplus lands.

3.2 ASSUMPTIONS FOR POTENTIALS ESTIMATES

BASE METHOD for biomass potential assessment was used for the review of the biomass resources in Europe. In chapters 4-10 results of literature survey were presented. Data on biomass resources potential deriving from different national estimations and statistics were provided. The intention was to verify Base method resource-focusing calculations based on fixed assumptions and find out the specific country ratios of residues available for energy and also discuss current demands and use of biomass potentials.

In chapter 11 biomass potentials from agriculture, forestry, wood industry sector as well as energy crops opportunities are presented. Results are the compilation of data from EU-databases, literature data and the RENEW partners' knowledge about biomass potentials. A discussion of any restrictions for available energy potentials specific for different countries was also provided. Restrictions relate to: (i) any estimates of competitive demand of straw in agriculture, (ii) wood-industry by products market demands (e.g. recycling of by-products for wood-products and energy), (iii) utilization practices and current extraction of forestry residues in different EU regions. Finally, a comparison of the results of theoretical values from Base method and the RENEW fact-finding data is possible.

The potential-defining schemes from chapter 2 were completed by some comments resulting from the literature survey and are presented below. Additionally, for each type of biomass resources: agricultural residues, forestry and wood industry residues and energy crop guidance for methodology were provided. The methodology will be developed in as a next step after the biomass potentials revision in this report. So far the biomass potential assessment was made on the national level. Further on, in the course of the project more precise analysis is expected.

3.2.1. Agriculture residues

FAO statistics from BASE METHOD on agriculture land was reviewed with national statistics. Based on the literature review it was estimated, how large volume of agriculture residues (cereals straw and maize stalks) are available for energy use and especially for BtL fuels production. Competitive demands were taken into account. Regional straw and maize residues utilization for agriculture purposes (animal bedding, litter, ploughing in the fields, mushrooms cultivation, etc.), the current use for energy production and import/export balances were reviewed.

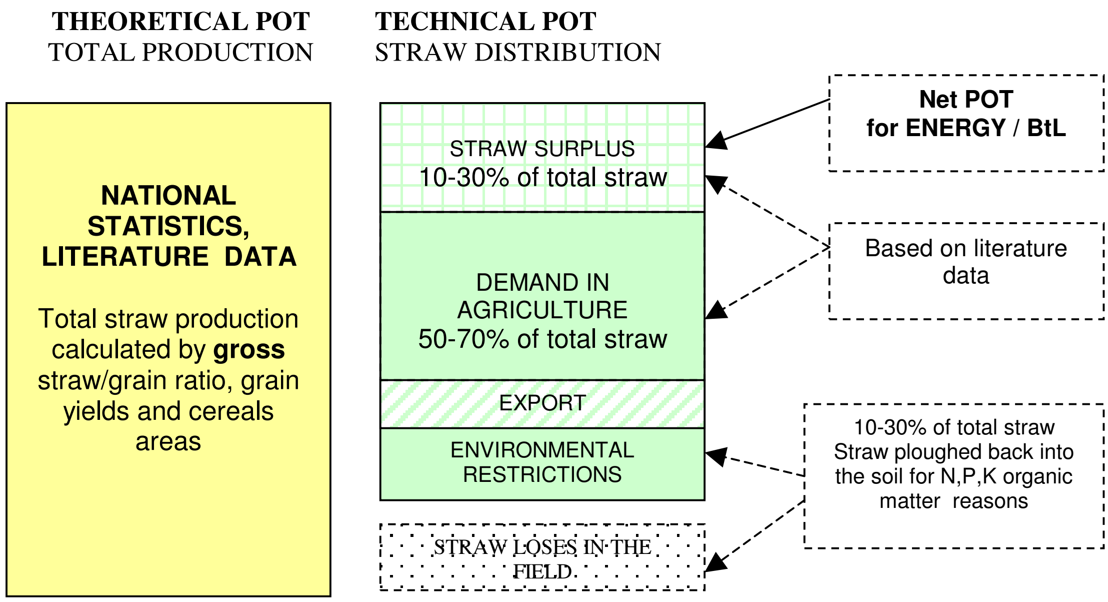


Figure 10. Scheme of straw potentials estimates method.

In each EU region we investigated and assumed certain ratios of agricultural residues surplus, contrary to BASE METHOD fixed ratios were used (0.22 t surplus straw/t cereals grain; 0.25 t surplus maize residue / t maize grain). The ratios results varied: 0.1-0.3 t straw/t cereals grain, and for maize: 0.1–0.6 t residue /t maize grain. There were also countries with no straw surplus available. For Southern Europe countries, residues from permanent crops such as fruit (almonds, peaches, apricots) orchards, vineyards, and olive orchards were also included in the calculations

3.2.2. Forestry potentials

The *Theoretical potential* of forest residues is based on the net annual wood felling, not net annual wood increment (yearly growth of forests). The *Theoretical potential* was calculated based on current national felling [Mm^3/y^{-1}].

Currently the average felling rate of timber-wood from forests in the EU is lower than 100%, about 61% in the EU15 and 77% in the ACC10. Overall, the growing stock in European forests has been projected to increase by 27% by 2020 compared to 1990. Final felling and thinning operations enable the harvest of forest residues, i.e. tops and branches and root and stump wood, also undergrowth trees (wood – from clear cuttings or thinning). The potential volume of logging residues and thinning wood varies with species and age of the trees. Residues extraction depends on the forest type, location (i.e. in mountain areas and on sensitive soils wood removal is limited) and management rules of each country. In some countries forestry policies do not support extraction of 100% rate logging residues and limits extraction of root and stumps due to ecological reasons. The residue to stem wood ratio for spruce/fir stands is roughly twice as much as for pine and three times as much as for birch (Savolainen, BENET 2000). The age of forests also influences the ratio.

TBFRA data on annual national wood felling were verified by national statistics (%felling rate in 2000). Then residue production~~s~~ rates relevant for forestry characteristics and experience in respective regions/countries were investigated in the literature. The national data on the thinning wood production were reviewed and calculated. Finally we estimated the relation of forestry residues potentials, current production, it's use in wood industry and for energy production and the fraction remaining as surplus potentials (see relation on the Figure 11).

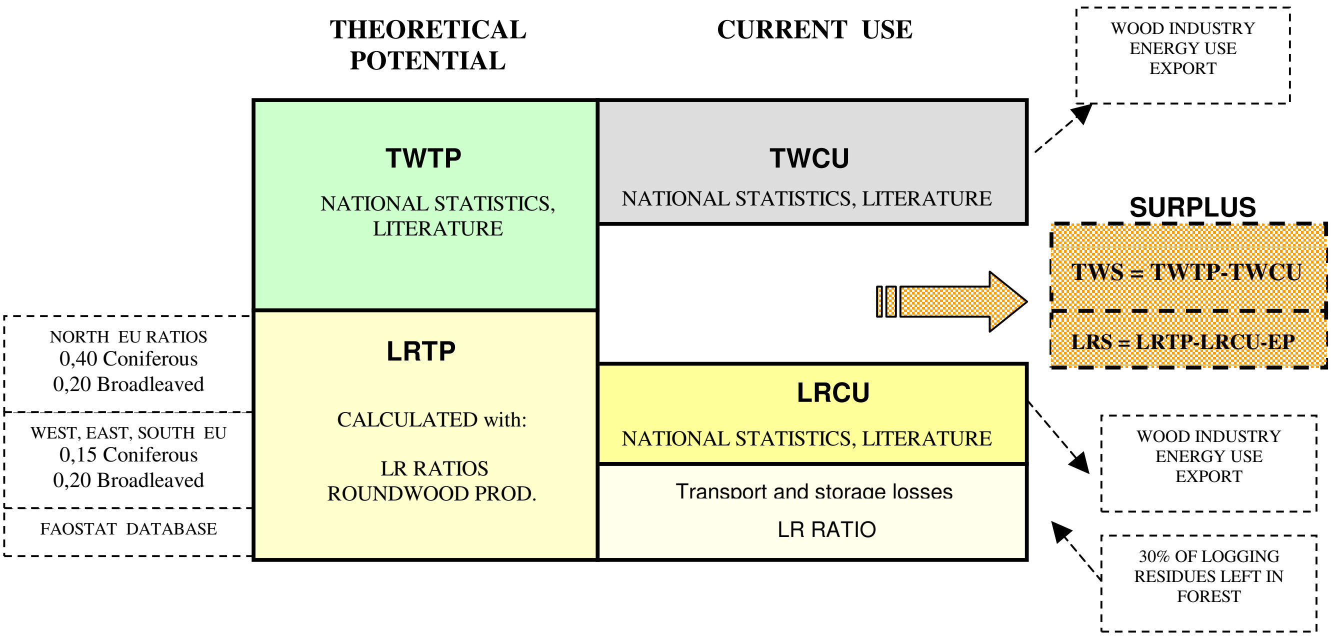


Figure 11. Scheme of forestry potentials estimates method, related to forestry residues utilization schemes and forestry residues market flows in EU

Table 2 Data sources in RENEW WP5.1 preliminary estimates of forestry residues potentials

TWTP (thinning wood theoretical potential) – BASED on national statistics and literature; volume of wood from commercial and pre-commercial thinning
LRTP (logging residues theoretical potential) - CALCULATED with wood from final felling (Round wood Production data from FAOSTAT Database) and logging residues ratios for coniferous and broad-leaved species. The ratios were different for Northern Europe (main species Spurs) and the rest of Europe (the main species Pine, Oak and Beech)
TWCU (thinning wood current use) – BASED on the literature data, current utilization of thinning wood in wood industry, for energy production, export
LRCU (logging residues current use) – BASED on the literature data, residues utilization/demand in wood industries: 1. pulp&paper production, 2. particle boards production, 3. for energy production and 4. other needs – agriculture, gardening (based on literature/national statistics)
EP (ecological potential) – logging residues that should be left at forests (spread at felling site) due to nutrients N,P,K recycling, sensitive soils protection etc. (based on national R&D recommendations and legal rules), LR ratio = 30% of gross potential of logging residues
TWS (thinning wood surplus) – CALCULATED as net surplus [impose current market demands and flows]
LGS (logging residues surplus) - CALCULATED as net surplus [impose current market demands and flows]

3.2.3. Wood industry potentials

The estimates of wood industry potentials meet~~s~~ strong difficulties as wood by-products are demanded by wood industry for production purposes, energy sector and agriculture. Wood by-products are utilized as well for their own energy needs in wood industries. In pulp and paper mills, bark and black-liquor are the main by-products. Both are with high-rate internally consumed in pulp-mills for heat and power generation. Part of the bark is also required for agriculture and gardening.

In sawmills, the main fractions of by-products are: chunk-wood and sawdust. Part of the by-products is internally used for heat production in sawmills (for wood-drying and their own heat consumption), whereas rest chunk-wood is usually chipped and then might be used by particleboards factories, mechanical pulp-mills or for energy production. Respectively raw material or by-products are processed into pellets and briquettes and then used in the domestic sector, district heating or CHP plants. Others wood sectors (joinery production, furniture, particle-boards) generate dry powder, which is often used for heat production at plant. However those industries might also use by-products from sawmills for energy production. Also there are regional differences in wood-by products flow due to diversification of forestry resources, wood –processing industry and pulp-industry around Europe.

Based on the mentioned facts, it's relatively difficult to estimate the theoretical flows of wood-industry by-products as well as collect source-based data on the by-products potentials. Figure 12 presents a simplified scheme of the wood-industry by-products flows in the EU.

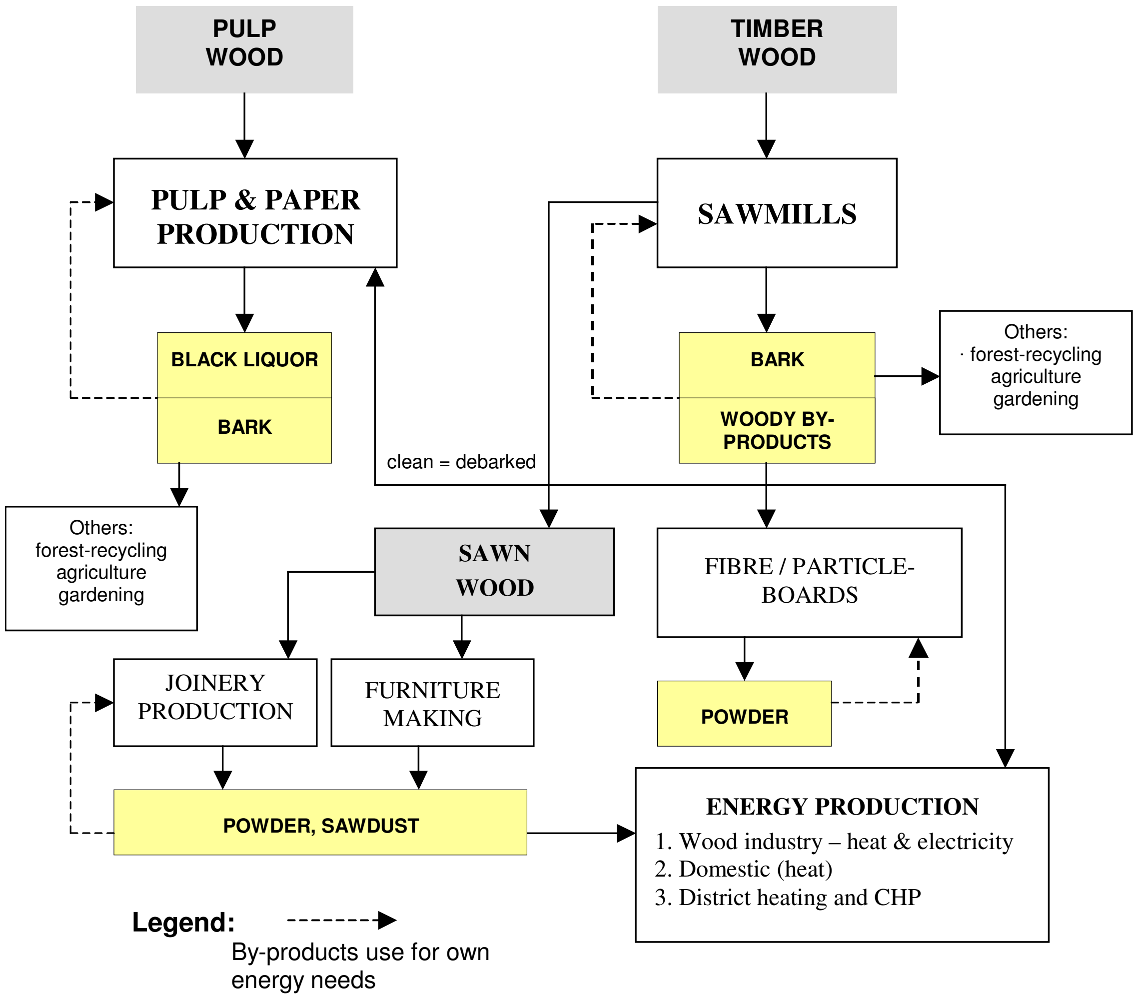


Figure 12 Scheme of wood-industry by-products market demands and flows in EU.

All round wood removals (excluding fuel-wood) are assumed as used in the forest industry (pulp and paper mills, saw-mills) as in the BASE METHOD. Then we assumed that a different ratio (%) of round wood removed from forestry is turned into final products around Europe. We reviewed studies on wood industries and based on national data of wood by-products flows, by-products demands and surpluses were estimated. All over the EU woody industrial by-products flows and demands vary from country to country on the basis of the forests management, the wood-industry structure and technology development. Fe. states in CEE-8 countries by-products are used for pulp and paper production, particleboards production, energy production, agriculture and horticulture and any surpluses are very limited.

In BASE METHOD, it was assumed the fixed ratio (20%), a 1/5 of round wood removals to be by-products (bark, saw dust, wood chips and black liquor) would be available for industrial or energy purposes. The share of available by-products (20% of felled round wood) was a rough approximation.

3.2.4. Energy crops

Energy crops potentials were estimated for the mid/long-term (20-40 year). We expect larger potentials in comparison to the biomass form agriculture, forestry wood industry which is not expected to change much in the future. As in the Base-case assumption, 0.24 ha/capita demands for food production of agricultural land was applied. Energy crops potentials cultivation was limited to 50% of the pasture lands. The estimates were revised based on the best available information about energy crop~~s~~ yields obtained in the research trials and commercial cultivation around Europe. The assumed yields of energy crops vary in relation to: (i) R&D results and experiences and (ii) expected % increase in relation to the average wheat yields in countries.

Table 3 Summary of methodologies assumption for biomass potentials assessment

	Comment
Forest residues FR	Reflects to annual wood removals ‘2000 year Ratios investigated in different countries: (tonne residues / tonne stem wood) Residues fractions reviewed in statistics included: (i) logging residues, (ii) thinning wood (clear-cuttings, pre-commercial cuttings)
Wood industry by-products FB	Reflects to literature-based data on wood industry by-products flows in countries (i.e. consumption by wood-industries in production processes, consumption for energy needs, estimates of market surplus)
Agriculture residues CR	▪ based on the average cereal crop yields (1998-2002) from FAO data base ▪ residue generation ratios varied around Europe: 10% - 30% total straw production; 10-20% residues / tonne maize and it’s based on the literature/R&D data obtained from previous regional and national studies ▪ permanent crops residues production calculated as 0,88 tons DM $y^{-1}ha^{-1}$, (20% production assumed available for energy)
EC_2004-2020y	▪ area for energy crops: current set-aside arable land in all EU-25 (‘2000 year), yields: average based on results of research and demonstration trial fields (varies in different countries 4,5-14,7 tons DM ha^{-1} y^{-1}

EC >2040y	▪	area for energy crops: (i) agricultural land that is not required for food production, which claims 0.24 ha/capita and (ii) 50%* pastures area conversion rate for e-crops, yields: 2*(current average wheat yields) + 40% increase in CEE-8 and 20% increase for EU-15 (effect of good agriculture practices learning for e-crops until 2020y).

3.2.5. Calorific values for biomass

Resource	**NCV [MJ/kg]**	**Comment**
Forestry: logging residue and thinning wood	6.9	Fresh, wet as received during forestry stands felling (50-65% moisture)
Wood industry by-products	10	Assumed as partly-dried (thus NCV is higher than forestry residue)
Agriculture: Cereals straw	14.4	As received in the field (15-25% moisture)
Maize straw	7	As received in the field (15-25% moisture)
Permanent crops res.	18	Data presented as dry-basis (DM)
Energy crops (woody and herbaceous)	18	Dry basis

4. REGIONAL STUDY EAST EUROPE (EC-BREC)

Chapters 4-9 contain an overview of literature data on biomass resources and potentials. Different national studies and reports were investigated to find out the statistics or estimations of biomass resources available for energy from agriculture, forestry and wood industry sector. It is primarily based on national studies, however reports of European Commission and others' were also revised. Where necessary, use was also made from the FAOSTAT database, e.g. to present the cereals area or yields. The data presented in the chapters are from different years, however most figures relate 2000. For some countries different estimations relating the same biomass resource were found and presented, what results from different assumptions of the biomass potential calculations. The aim of the literature survey was also to find out about the specific conditions in different countries and European regions relating the use of biomass resources. Any issues related to bio-energy national polices and strategies were also presented.

4.1 AGRICULTURE RESIDUES

Cereals straw is the primary agriculture residue in the central-east European region. Cereals cover between 20% and 47% of the total arable land. Among the countries with the highest share of cereals are Slovakia, the Czech Republic and Poland. On the contrary Latvia and Estonia have the lowest share of cereals. Obviously the geographically largest country, Poland, has the largest absolute straw biomass potential. The structure of sowing area is different among these countries. In Poland, the Czech Republic and Slovakia, wheat is the dominant crop. In Hungary and Slovakia, maize has the same share in the cropland as all small grain cereals. In Estonia and Latvia, barley is the dominant cereal. In Hungary, there is also a significant potential of sunflower shells and grape pruning.

Table 4 Cereals and cereals straw potential in CEE (FAO, 2002; partners data)

	Cereals		Cereals yields average 1998-2002	Straw surplus available for energy
	1000 ha	**Share in arable land**	**t/ha**	**Mt/year**
Czech Rep.	1433.2	0.5	4.2	1.07
Estonia	262.3	0.2	1.8	0.15
Hungary	1538.0	0.3	3.6	1.98
Latvia	377.1	0.2	2.1	0.57
Lithuania	793.0	0.3	2.5	0.40
Poland	5850.0	0.4	3.0	7.50
Slovakia	684.0	0.5	4.1	0.54
Slovenia	52.5	0.3	2.3	0

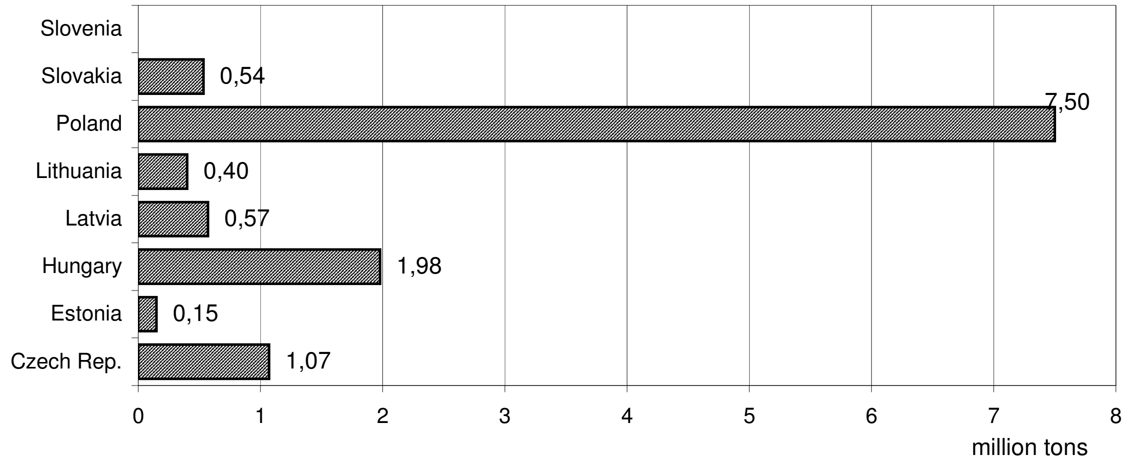


Figure 13 Straw potentials in CEE countries (numbers represents straw surpluses available for energy use or any alternative utilisation beside agriculture purposes)

Czech Republic

The utilized agricultural area (UAA) was 4.2 million ha in 2000. The area used by cereals increased to 38.3%. The wheat area of 0.92 million ha represents 59.0 % of the total cereal area in the Czech Republic and another 0.57 million ha or 30.1 % of cereals area is used for barley. Maize, oat, rye and other cereals all together have a share of about 10 % of the cereals area. Fodder crops used 0.74 million ha or 17.3 % of the total agricultural area. Other important crops are oilseeds, which covered 8.3% of UAA; mostly rapeseeds are planted. The cereal yields are fluctuating between 3.9 and 4.4 t/ha (DG Agriculture-Country report on the Czech Republic, 2002).

The current straw fuel utilization is 0.5 PJ: cereal and rape straw (Neuzil and Vacek, 2004). It was estimated that the future biomass utilization potential of straw fuel would range between 1.3-3.5 PJ in 2005 and 23-28 PJ in 2010. Straw is used for local briquette and pallet production lines, but it is too limited. In the total number of implemented biomass projects the share of straw fuel is 8% of the total amount of biomass fuels.
In the Country Survey prepared in the framework of ERA Bio-energy project the straw potential was estimated at 15 PJ/year, which is the equivalent of 1.07 million tons (Era Bio-energy, 2002).

Estonia

The agricultural area amounts to 1 million ha. Cereals used close to one third of it or 351,000 ha. Nearly half of the cereals area (47%) was planted with barley, followed by wheat (20%), oats (17%) and rye (10%). Other important crops are potatoes. The average cereal yields was1.74 t/ha in the period 1992-2000 (DG Agriculture-Country report on Estonia, 2002).

Currently 25% of the total straw production, which equals 100-150 thousand tons, may be used for energy purposes (Muiste et al., 2004). In the future, with more intensive cereal production, the amount of fuel straw could increase to 200-250 thousand tons. It would be possible to produce at present 0.4-0.6 TWh of energy with the use of straw, while in the future the corresponding amount could be 0.8-1.0 TWh. At the current level of straw production it would be equivalent to the caloric value of 35-54 thousand tons of liquid fuel. The annual potential of cereal straw for energy production on the Estonian Islands is 30,000 tons (Muiste et al., 2004). It makes up 60% of the potential straw crop. There are 3 boiler houses in

Estonia. The installed thermal capacity is 0.5-0.8 for each boiler. The potential energy production is estimated to be 1,300 TJ/yr (BEF, 2003).

Hungary

Currently, cereals use nearly half of the agricultural area of 5.8 million ha. The area used for cereals has increased from approximately 46.3 % in 1992 to 48.1 % in 2000 (59 % in 2001). The maize area of 1.2 million ha represents 44.2 % of the total cereal area in Hungary. Another 1 million ha or 36.3 % of cereals area is used for wheat and 10 % of cereals area is planted with barley. Oilseeds have a share of 8.1 % of UAA and sunflower amounts to two-thirds of this total. The cereal yields are fluctuating around 4.8 t/ha (DG Agriculture-Country report on Hungary, 2002).

The potential of agriculture by-products (cereal straw, stalk, vine-shoot) is estimated at 7-8 million tons (Marosvolgyi and Vytyi, 2004). Fenyvesi and Pecznik estimated the agricultural by-products potential at 37.9 PJ per year (Fenyvesi and Pecznik, 2004). This includes the following: straw 27.7 PJ (which is the equivalent of 1.98 Mtons), sunflower shell 1.4 PJ, fruit tree pruning 4.4 PJ, vine-shoots 1.4 PJ and others 3 PJ. The current production of energy from agricultural residues is 2 PJ per year, which makes up 3.3% of the energy produced from biomass in Hungary.

Table 5: Utilization of crop residues in Hungary (Ministry of Economics, World Bank, CSO, 2001)

	Utilization, PJ per annum	Share in the renewable
Sunflower shell	1.4	3.9
Corn cob	0.4	1.1
Straw	0.15	0.4

Latvia

The utilized agricultural area (UAA) of Latvia was 2.5 million ha in 2000 (EUROSTAT). The crop area was 0.96 million ha of which cereals make up 44%. There was a rapid fall in the area allocated to cereal production, however since 1995 it remains fairy stable. Fodder crops make up also about 44% of the total cropland. Average cereal yields increased from 1.6 t/ha in 1992 to 2.2 t/ha in (DG Agriculture-Country report, 2002) (DG Agriculture-Country report on Latvia, 2002).

The total straw potential is estimated at 2.9 PJ (ERA Bio-energy- Country Survey, 2002). Of the total straw production, only a small part is used now for energy purposes (Shipkovs et al., 2004). The major part is used in agriculture's own production such as bedding in livestock housing systems etc. The straw available for energy production is estimated at 0.15-0.57 million tons (BEF, 2003). There is only one straw boiler house of the installed capacity 1.36 MW. The potential energy production was estimated at 2,200 TJ/year.

Lithuania

The utilized agricultural area (UAA) of Lithuania was 3.5 million ha in 2000. Cereals area had a share of 28% and amounted to 0.98 million ha. Wheat and barley had nearly the same share (about 36%) in the cereals area, with the tendencies of a heat increase due to a governmental support programme for wheat (DG Agriculture-Country report on Lithuania, 2002). The average cereal yield was 2.54 t/ha (Vrubliauskas and Pedisius, 2004).

The total production of straw is approx. 3.5-4 Mtons per year in Lithuania. But not all this amount of straw is collected. Part is left in the fields as loses. A large part is consumed as litter or fodder. Some part is ploughed into the soil, used in gardening and for other purposes, for example preparation of substrate for the growing of mushrooms, etc. It is assumed that about 10-12% of the total amount of straw or approximately 400 thousands tons could be used for energy production, that corresponds to 7.02 PJ of energy. It could contribute to the reduction of imported fuel by 1.5%. The pilot straw-firing boiler was installed in the country in 1996. At present there are 11 boilers with the unit capacity of not less than 0.34 MW, the total capacity being about 7 MW. Today consumption of straw fuel is estimated at 2.8 ktoe of the primary energy. Several Lithuanian companies manufacture the straw combustion equipment. Furthermore, new straw combustion technologies are also developed in Lithuania and local manufacture of equipment is in progress (Vrubliauskas and Pedisus, 2004).

Slovak Republic

The total agricultural area is 2.44 million ha. Cereals use just over one third, which is 0.86 Moa. The most important crops by area used are wheat, barley, maize and the oilseeds (rapeseed and sunflower). Wheat accounts for 48 % of the cereals area with around 0.41 million hectares. Another 0.24 million ha or 28 % of the cereal area is allocated to barley production and a further 0.14 million ha or 16 % is planted with maize. While cereals remain the most important crops, the oilseeds area has increased in importance and accounts now for around 8% of the UAA. Average cereal yields fluctuated close to 4 t/ha (DG Agriculture-Country report on Slovak Republic, 2002).

The technical potential of agricultural residue in the Slovak Republic is estimated at 8,359 TJ of which only 2.6% is currently used for energy purposes (ERA Bio-energy - Country report, 2002). The biomass available for energy purposes amounts to 535 thousand tons annually (EGU Bratislava, 1999).

Slovenia

Currently, the cereal area represents about 100,000 hectares. The maize and wheat areas are about 50,000 hectares and 40,000 hectares respectively, and only relatively small areas are devoted to barley, oats and rye. The area devoted to oilseeds is also relatively minor, but it seems to have increased recently, especially in North East Slovenia. The area under permanent crops (fruit, hops and grapes for wine) accounts for around 60,000 ha of UAA and are very important in economic terms. The average cereal yields is close to 5.8 t/ha (DG Agriculture-Country report on Slovenia, 2002).

The main biomass sources in Slovenia are wood from forestry and wood waste from the wood manufacturing industry. More than 56 % of the land in Slovenia is covered with forest. Biomass from agriculture (agricultural wastes and orchard pruning) is not used for energy purposes(ERA Bio-energy, 2002). Straw (excluding the maize stove) is used in general for bedding and as animal food. The maize stove is almost entirely ploughed in.

Poland

In 2000 there were 18.4 Mha of agricultural land, including 14.06 Mha of arable land (76% of total agriculture land). Cereal production is dominant and is still increasing in the share of cropland. Main cereals (wheat, rye and barley) were grown on 8.85 Mha. Wheat is a dominant crop (30% of the total sown area). The average for 1999-2001 of cereal straw production amounted to 25.7 Mt/yr (GUS, 2002). After taking into regard the straw requirements for agricultural usage – bedding, fodder and ploughing – straw surpluses may be used for other purposes such as energy production. According to two different studies the surpluses of straw in Poland amounts to 3.8 Mt/yr (Smagacz, 2003) or 11.1 Mt/yr (Grzybek et al., 2001). This is the equivalent of 53.2 PJ or 155.4 PJ primary energy. The difference results from different assumptions taken for the calculation of straw requirement for bedding and fodder. We assume that the potential of straw available for energy is **7.5 Mt** what equals **105 PJ**, which is 30% of total straw (ECBREC own estimations).

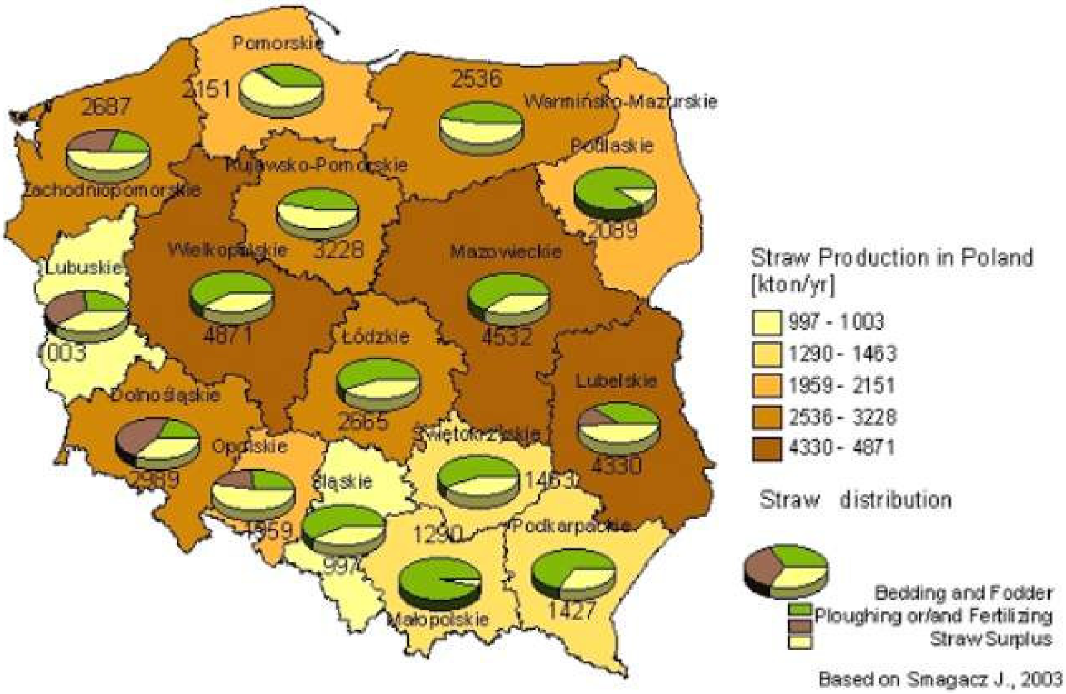


Figure 14: Straw production and potentials distribution in Poland (Smagacz, 2003)

Cereals production is the most common in the central and northern areas. The largest surpluses of straw are in regions of high cereals production and relatively low animal stock, this is in the north and two central-southern regions. Energy production based on straw is located mainly in northern Poland where straw production is high and the farm area is higher than average for Poland. Straw export/import is not developed. The use of straw for energy was estimated on 40,000 tons in 2001 (0.5 PJ). There are about 40 small and medium scale (0.5 – 7 MWt) straw fired district heating plants, and perhaps 100-150 straw boilers in agricultural farms. Other competing is insignificant.

4.2 FORESTRY RESIDUES

Poland

The area covered by forests is estimated at about 9.1 Mha, which equals 28% of the country territory (Forestry Statistics, 2003). In the ownership structure, public ownership dominates with 83% of the forest area – forest under management of the State Forests State Forests National Forest Holding (NFH) equals 78%, National Parks – 2%, other public 3%, private forest area is calculated as 17% in which 16% equal forests of private persons.

Average stand density increased as a result of the systematic management. Dominate forests in 3-4 age classes (41-80 years old) – 42% of total forest area and 51% of growing stock. Generally the biggest stocking density is located in 2-5 classes (21-100 years old). This age structure is connected with the forests' devastation under the Second World War and later forestation.

Almost 80% of the growing stock volume is made up of coniferous species, of which Scots pine is by far the most important; The broad-leaved species equal nearly 20%, but this share is still growing. Oak is the major broad-leafed species, others are beech and birch.

The total growing stock in all forests is calculated at almost 1800 Mm^3. The annual increment is estimated as 50 Mm^3/yr. The felling is equal to 30 Mm^3, that is 55-60% of the growing stock.

Table 6: Wood production in Poland 2002 (FAO database, 2004)

Production [cum = m^3]	Total	Coniferous	Non-coniferous
Round wood	27,170,000	19,855,000	7,315,000
Saw logs + veneer logs	10,716,000	8,552,000	2,164,000
Pulpwood, round & split	12,600,000	8,800,000	3,800,000
Fuel wood	2,130,000	1,100,000	1,030,000

40% of felled wood is harvested in final cuttings and 60% in intermediate cuttings of which 77% is in thinning cuttings. Mainly coniferous wood is harvested (72% of harvested wood) - it is connected with the species composition in Poland. The volume of felling is planned to increase in the future.

Table 7: Average annual harvesting of 3-sorts of potential energy wood in PL [in dam^3] (Rozański J, 2002)

Years	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Fuel softwood	970	1205	1401	1216	853	487	523	536	476	477	583	620
Fuel hardwood	790	1171	1318	1094	878	587	638	690	703	754	719	818
Small size timber	561	654	801	736	968	880	974	998	924	929	919	944
Woodchips*	692	640	741	558	621	446	353	713	440	317	223	190

* the amounts of woodchips do not refer only to fuel woodchips but also woodchips used for wood cellulose, felt plates and chip plates production

The potential annual energy wood supply from the State Forests in the period 2000-2010 was also assessed by app. 1.5 Mm^3/year of potential wood available for energy, and 15.3 Mm^3 available within the decade 2000 – 2010 (Rzadkowski, 2000).

Table 8: Forestry wood potentials for energy until 2010 (Rzadkowski, 2000).

Feature	[dam^3]
Middle-sized wood	12 256
Small-sized wood	2 839
Logging residues (LR)	265
Potential medium- and small-sized wood supply	**15 260**

According to forestry researchers a majority of small-size wood from the thinning operation shall be harvested and chipped at the felling site in regards to the effectiveness of harvesting, transport and combustion processes. Thus, the requirement for equipping the forestry service in eligible chipping machines has arisen. Domestic heating wood is divided into the shape of chopped logs (1 metre long and stored close to out-way forests roads). According to the IBL prognosis the majority of fuel-wood potentials in 2010 shall be extracted as small-size trees from thinning operations (Rzadkowski, 2001).

The State Forests National Forestry Holding (NFH) made official estimations of fuel-wood potentials in 2003 (Wojcik, 2003). The NFH presented the current production of energy-wood (fire-wood and wood-chips) at the level of 3.2 Mm^3. Based on the study, it is also possible to increase the current fuel-wood production up to 6.1 Mm^3 mainly from extraction of small-size wood and logging residue, however the economy is the leading factor to reach it. Table 9 presents the fuel-wood production quantities and estimates of possible production increase in State Forests.

Table 9: Fuel wood production in the State Forests [Mm^3] (Wojcik, 2003)

Specification	Current production	Possible amount of increase
Firewood	1.5	0-0.2
Pulpwood for fuel	0.8	0.4-0.5
Small-size wood	0.9	0.5-1.0
Logging residue (LR)	0.2*	0.7
Stump wood	0.0*	1.3
Total	**3.2 Mm^3**	**1.1-2.9 Mm^3**

* currently not harvested due to cost-inefficiency

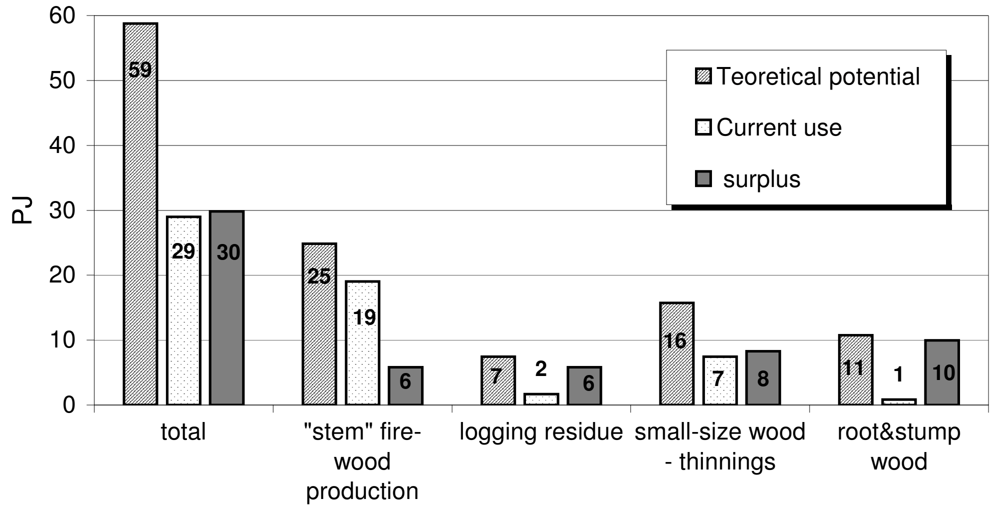


Figure 15: Forestry wood potentials and current demands for energy and wood industry use (Forestry Statistics, 2001)

Logging residues (LR) generated at the felling stands includes branches and tops. Part of the 0.2 Mm^3 logging residue extracted in State Forests is currently utilized as firewood, and part is chipped and sold for particleboards production. After the application of traditional logging methods in PL, logging residues is contaminated with sands (thus quality is lowered). Common methods of logging residues utilization in Poland are: (i) residue removing for firewood, (ii) residue burning at road-site, (iii) residue chipping and spreading at felling site. The most common way still has been pilling beside the strip and fire roads. The forestry potentials available for energy were estimated at: 0.9 Mm^3 logging residue, which corresponds to 6.21 PJ. Thinning resides potentials were estimated at 2.5 Mm^3 (Różański and Jabłoński, 2003)

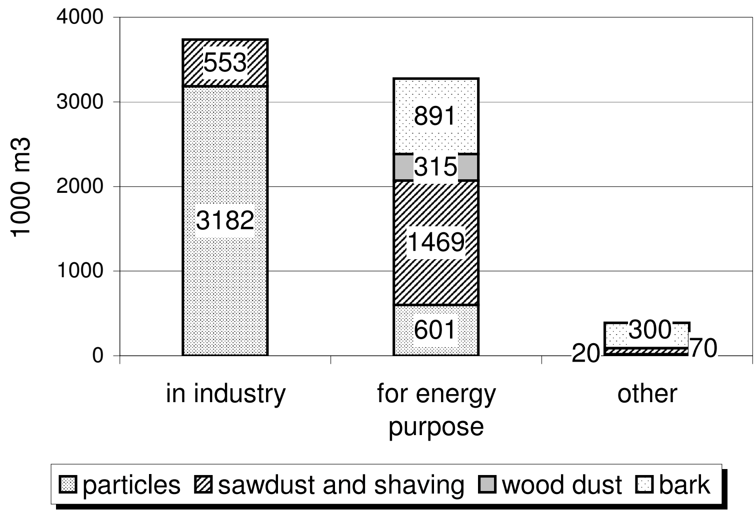


Figure 16: Utilization of wood by-products in Poland in 2001 (Szostak, 2003)

Czech Republic

The area covered by forests in the Czech Republic is estimated at about 2.6 Mha, which equals to 33% of the country territory (FAO, 2004). The ownership structure of forests is characterised by the restitution process. The transformation of the state-owned forest enterprises has been completed, by splitting them into parts, which are to be privatised, parts, which are to be managed by the state, and parts for restitution claims. Forest ownership structure in 1998 was following: state 63.4%, communal 12.8% co-operatives 0.8% and private 23% (Ministry of Agriculture CR, 1998) Average stand density increased from the beginning of the 1980s as a results of the systematic management. Dominate forests in 2-3 age classes (10-30 years old). Generally the biggest stocking density is located in 1-6 classes (1-60 years old).

Coniferous species make up more than four fifths of the growing stock volume, the main species being Norway spruce, European larch and Scots pine. Beech is the commonest broadleaved species, others including oaks, poplars, birch, maple and willow. Area of coniferous species in 1998 was estimated as 77.6%, broadleaves 22.4% (Ministry of Agriculture CR, 1998).

The yearly harvesting of wood in the Czech Republic comes to approx. 14.5 Mm^3, that is about 78% of total current increment. It can refer to energetically renewable potential of wood mass at the extent of about 3.5 Mtons of wood mass (Neužil V. 2002). The growing stock volume per hectare is calculated as 233 m^3/ha and total grooving stock was 615 Mm^3, and is among the highest in Europe. The total mean increment is estimated as 16.6 Mm^3 (6.4 m^3/ha) and total current increment as 18.4 Mm^3 (7.1 m^3/ha) and it is well above the European average (FAO, 2004)

Table 10: Wood production in Czech Republic 2002 (FAO, 2004)

Production [cum]	Total	Coniferous	Non-coniferous
Round wood	14,541,000	13,010,000	1,531,000
Saw logs + veneer logs	8,073,000	7,580,000	493,000
Pulpwood, round & split	5,081,000	4,420,000	661,000
Firewood	1,007,000	650,000	357,000

There was an evident growing tendency of fellings in the first half of the 1980s. The short time drop of fellings in 1991-92 arose during the restitution process but since 1993 the growth of fellings has increased again and equals 13.99 Mm^3 (coniferous 12.25 Mm^3, broadleaves 1.74 Mm^3). The total extent of thinning and cleanings is higher than before 1990. The total area of thinning increased significantly and equals 0.13 Mha. The area of cleanings equals 0.05 Mha.
The total production of fuel wood in 2002 was estimated as 1 Mm^3 and consumption was 0.80 Mm^3 (FAO, 2004). Firewood, forestry and wood industry residues total theoretical potential is estimated as 52.5 PJ/yr and the total available potential as 32.5 PJ/yr (Neužil and Vacek, 2002).
For wood residues in the year 2005 as a low target it is estimated at 24.4 PJ and in the same year as a high target 28.0 PJ. Assessment for the year 2010 was: for low target 28.5 PJ and for high target 35.7 PJ (Neuzil and Vacek, 2004).

Estonia
The area of woodland in Estonia is 2.25 Mha (51.5% of land area) The forest area has increased by 2.2 times during the last 60 years (Muiste et al., 1997). The ownership structure has changed considerably in the course of the land reform. As a result of the restitution and privatisation processes, many land plots that had been left out of active management, now have owners. The state forests constitute about a half of the total forest area, and the resituated and privatised forests are about 19% (FAO, 2004). The analysis of the age structure showed, that the biggest areas of forest will reach maturity during the coming 11-20 years period, quite a lot during the next 10 years and after 20 years the areas will start to decrease. The age structure of state forests is quite even and therefore big changes in harvesting volumes will not take place.
Forests are mainly of the boreal type: coniferous species make up nearly two thirds of the volume of growing stock, predominantly Scots Pine and Norway spruce. The principal broadleaved species is birch, with alder common in certain localities. Most of the forests are available for wood supply
The growing stock is calculated as 462 Mm^3 and has increased by 3.0 times during the last 60 years, mainly as a result of timber suppliers from Russia during the last few decades.
The net annual increment of forest land equals 12-13 Mm^3 (BEF, 2003)
The harvesting is estimated at about 70-80% of the annual increment. The allowable level of utilization of forest resources fixed by the Forestry Development Programme 2001-2010 is relatively high, 13.1 Mm^3, due to the overbalance of middle-aged and mature stands in private forests (Muiste et al., 1997)

Table 11: *Wood production in Estonia in 2002 yr (FAO-Forestry, 2004)*

Production [cum]	**Total**	**Coniferous**	**Non-coniferous**
Round wood	10,500,000	6,920,000	3,580,000
Saw logs + veneer logs	3,360,000	2,860,000	500,000
Pulpwood, round & split	4,030,000	2,630,000	1,400,000
Firewood	1,930,000	1,050,000	880,000

Due to the big share of mature aspen and grey alder stands, in private forests the dominating assortment is fuel wood. If the private forest owners start to harvest besides merchantable assortments the low quality wood, the available quantities of fuel wood will decrease step by step. These figures show the theoretical potential, the real utilized quantities depend on the wood market and the behaviour of the forest owners. It should be underlined, that the trend of decline, describing the fuel wood supply from the private forests, is temporary. (Muiste et al., 1997)

According to the official statistics over the last years, the consumption of firewood has been about 3.2 Mm^3. It is obvious that there are remarkable resources of fuel wood not used at the present moment. The biggest potential for the future are the harvesting residues, which are seldom used today.

The potential from forest residues is still not efficiently utilised. The use of forest residues accounts for only 10% of energy production from wood-based fuels. Among the reasons for this is that residues are picked up manually due to the small area of clear cuts, as defined by environmental regulations. (Fammler et al.,2003).

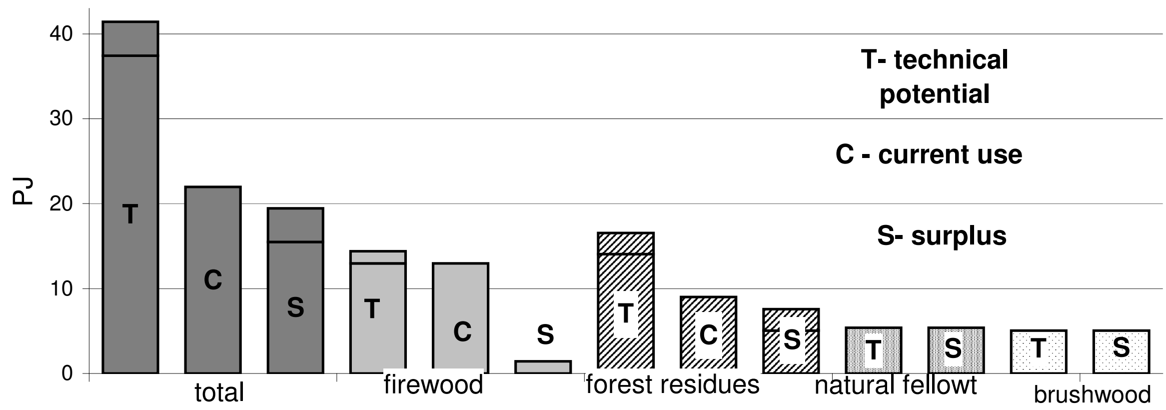


Figure 17: Fuel wood potential in Estonia (BEF, 2003)

The general data about the expected changes in fuel wood supply are presented in Table 12. The data indicates, that today we can use for energy production about 5 Mm^3 of fuel wood and forest residues, after 30 years about 2.3 Mm^3.

Table 12: Expected changes in fuel wood supply, Mm^3 (Muiste et al., 1997)

	Ownership	Fuel wood	Branches and tops	Total	Primary energy content, TWh
Potential yield today	Private	2.79	1.35	4.14	8.29
	State	0.44	0.45	0.89	1.79
	Total	3.24	1.80	5.04	10.08
Prognosis for the year 2030	Private	0.58	0.94	1.52	3.04
	State	0.38	0.38	0.76	1.52
	Total	0.96	1.32	2.28	4.56

In one of the recent studies technical potential of logging residues was estimated at 14 PJ (BEF, 2003). In other study in 2003 thinning residues potentials were estimated at 0.8 Mm^3, which equals to 5.52 PJ (Muiste, 2003).

Hungary

The area covered by forests in Hungary is estimated at about 1.8 Mha equal to 19 % of the country territory. The ownership structure is changing as a result of privatisation and restitution and is as following: 62% forest area is managed by state forest enterprises, 7% by state farms, other state organizations and local communities and 31% managed by co-operative farms and other organizations (Halasz et al., 1992). Young stands of up to 40 years old are over-represented as a result of restoration and forestation, and because of short rotations for some species (FAO, 2004). Broadleaved species make up well over 85% of the growing stock volume and over 84% of the forest area (1.3 Mha), one of the highest proportions in Europe, with oaks, beech, black locust and poplars; the main component of the forestation programmes being the commonest species. Scotch pine, Austrian pine, spruce are the main coniferous species.

The yearly wood removals comes to approx. 5.8 Mm^3, that is about 59% of the total current increment. The growing stock of productive forest is calculated as 229 Mm^3 and that of all forest to 288 Mm^3. Gross total annual increment equals 11 Mm^3 (in productive forest 9.2 Mm^3), the net total annual increment equals 9.9 Mm^3 (in productive forest 8.3 Mm^3) Tree felling was calculated as 7.4 Mm^3 (coniferous 0.69 Mm^3, broadleaves 6.73 Mm^3). Thus, wood waste at felling amounted to 20% of the total volume of production (1445.0 thous m^3). (Halasz et al.,1992). More then 60% of the felled wood is firewood or have similar value (Marosvölgyi, 2004)

Table 13: Wood production in Hungary 2002 (FAO-Forestry, 2004)

Production [10^3 cum]	Total	Coniferous	Non-coniferous
Round wood	5.836	620	5.216
Saw logs + veneer logs	1.860	140	1.720
Pulpwood, round & split	622	291	332
Firewood	2.398	43	2.355

Firewood represents 46.3% of the total wood removal, and about 50% of industrial wood including import round wood appears again as waste available for energy use during processing. This means that 79.4% of the total volume of felling could be considered as theoretical potential. Deducting the volume of industrial use and parts, which cannot be economically collected from the felling site is 53.1 PJ/y energy that can be considered from average the total gross wood production (theoretical potential) (Fenyvesi and Pecznik , 2004)

The technical potential (potential available) of fuelwood and by-products (firewood, woodchips) equals 45.3 PJ/ year. The potential already utilised is estimated as 23-28.9 PJ/ year PJ i.e. firewood and felling residues (AUA, 2000), where wood chips and wood wastes equals 5.4 – 10.6 PJ/ year (EB, 2002).

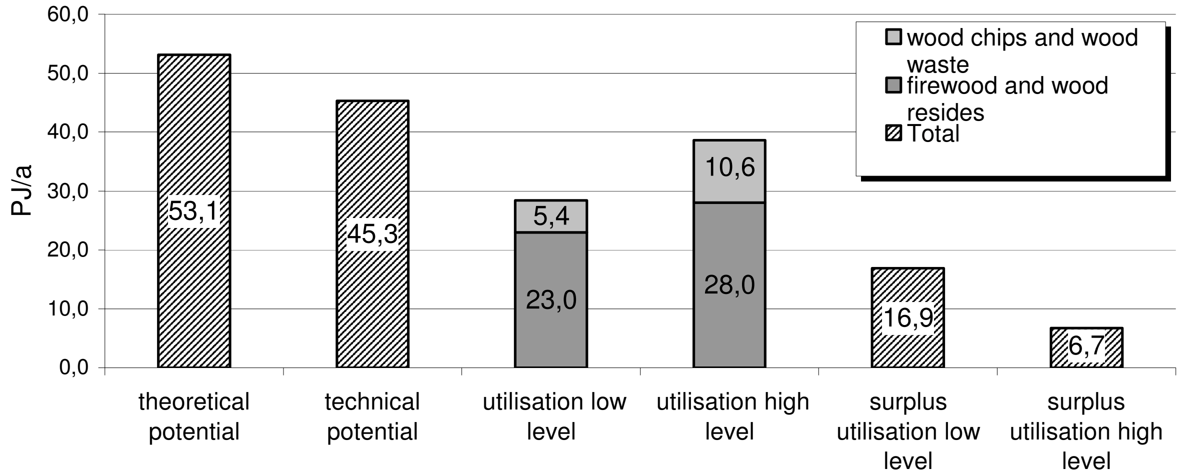


Figure 18: Potential and utilisation of wood biomass in Hungary (own estimates)

In 1995 tree felling was 6 Mm3 (gross) and waste at felling amounted to 20% of felled wood. Thus logging residues amounted 1.21 Mm^3 which corresponds with 8.35 PJ (Fenyvesi and Pecznik, 2004).
Due to different forestation programs, the volume of wood for energy purpose will increase, and its quantity depends on the rate of implementation of energy and close-to-nature forests.

Latvia

Latvia is well forested, with forest and other wooded land accounting for nearly half the land area; it is one of Latvia's major natural assets. The area covered by forests is estimated at about 28,840 km^2 equal to 45% of the country territory (FAO, 2004). More than half the area of forest and other wooded land is in State ownership, but the process of privatisation is continuing. Private forests equal 44% of the forest area, 52% is state forests, 3% forest of agriculture enterprises and 1% that are other forests (Shipkovs et al., 2004). Coniferous species account for three fifths of the growing stock, with one species, Scots pine, predominating, followed by Norway spruce. Birch is the main broadleaved species, with some volumes of alder, aspen and oak (FAO, 2004).
The growing stock volume is 544 Mm^3. The net annual increment is about 13 Mm^3 (6.4 m^3/ha) (BEF, 2003).
Felling has been increasing in recent years, but remains well below the net annual increment, with the result that the volume of growing stock has been raising. This is consistent with the fact that most of the forests are less than eighty years old (FAO, 2004)

Table 14: Wood production in Latvia 2002 (FAO, 2004)

Production [Cum]	Total	Coniferous	Non-coniferous
Round wood	13,466,840	8,552,210	4,914,630
Saw logs + veneer logs	9,860,540	6,532,410	3,328,130
Pulpwood, round & split	1,861,400	863,100	998,300
Firewood	1,198,000	670,000	528,000

The amount of woodcuts in the forests of Latvia has a tendency to have grown in the last years.
This increased cutting could be explained by the increase of firewood production for sale especially for export in private forests (Shipkovs et al., 2004)
The Parliament of Latvia has approved 10 Mm^3 of annual allowable cut in the coming years. It is quite real to increase firewood production in private forests. Resources of forests in Latvia allow increasing wood production without damage to nature up to 10-12 Mm^3 a year.

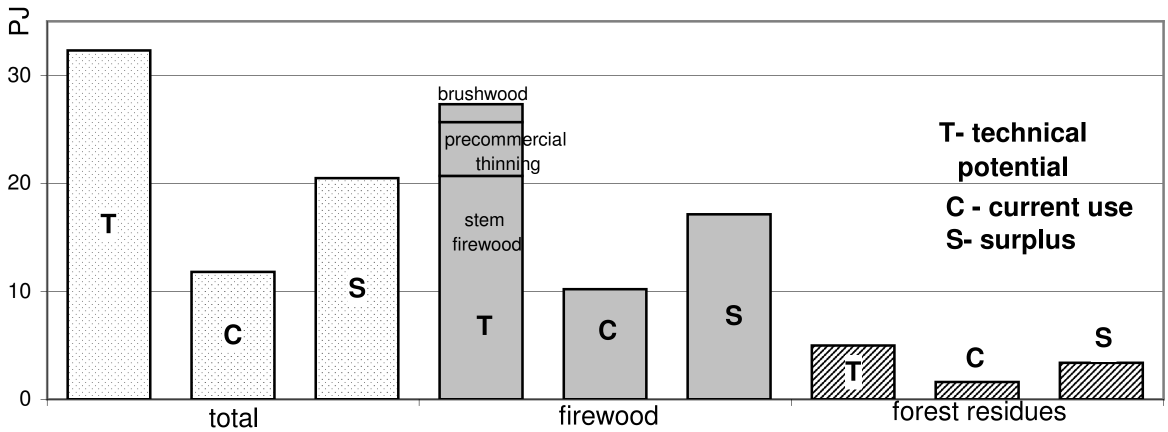


Figure 19: Fuel wood potential in Latvia (BEF, 2003)

The total potential fuel wood availability including firewood, forest residues, brushwood and wood processing residuals is presented in *Table 15* below.

Table 15: Potential volume of fuel wood in Latvia (M m3) (Shipkovs et al., 2004)

	1997	**2000**		**2010**		**2020**	
		Technical potential	**Energy use**	**Technical potential**	**Technical potential for energy use**	**Technical potential**	**Technical potential for energy use**
Allowable cutting	8.34	9.29		10		12	
Forestry - total	2.88	5.4	5.1	5.42	5.18	5.77	5.21
Fire wood	1.5	2.5	2.5	1.63	1.63	1.81	1.81
Tops and branches	0.6	0.7	0.6	0.8	0.8	0.9	0.8
Pre-commercial Thinning	0.5	0.6	0.6	0.79	0.75	0.86	0.7
Wood processing residuals	0.18	1.3	1.2	1.7	1.6	1.7	1.5
Brushwood	0.1	0.3	0.2	0.5	0.4	0.5	0.4

The technical potential of wood wastes for energy use was estimated and defined as 6.9 – 10.8 PJ per year for the years 2005-2010.
Resources of fuel wood are estimated as 840 ktoe. Today consumption of fuel wood is calculated as 620 ktoe and the total installed capacity of wood burning boilers as 260 MW.
A free market exists in Latvia for forest biomass. The fuel wood logs are sold at the roadside or transported by track to the end consumer and sold free delivered at the energy plant. Currently logging residues - tops and branches mainly are not taken out and used as fuel. The main barriers for the forest residue exploitation are:

- transportation cost as well as harvesting/handling cost are very high compared with the real price of the forest residues at the user facility;
- there are no regulations or directives, which could affect collecting of forest residues. (Shipkovs et al., 2004).

<u>Lithuania</u>

Forests cover 2020 thousand ha or 30.9% of the land area of Lithuania according to Lithuanian state forest assessment of 2001. The productive forest area is 1928 thousand ha. (Vrubliauskas and Pedisius, 2001)

Coniferous trees occupied 60.7% of all forest; the largest part is pine and spruce. 39.3% is broadleaves, mostly birch, black alder and aspen.
Middle-aged stands account for the major share of Lithuanian forests. The premature stands area is close to normal, while young and mature stands area is below the normal level.
The state forest occupies 1. Mha or 50% of the total forest area, private forestland amounts to 0.37 Mha, which gives 21% and 0.63 Mha (about 30%) to be reserved for restitution. (Baltrusaitis and Andersson, 2000)
According to statistics the felling volumes had settled during the last few years and are in the range of 5.5-6.3 Mm^3 per year, of which the largest part had come from the state forest. (MECFE, 2000)
The removable volume is going to increase and reach the level of 6.53 Mm^3 (2.71 from private and reserved forests, 3.82 from state forests) between the years 2001-2010 (Saladis, 2003).
In 1997-1999, the cleaning of young stands was carried out on 0.014 Mha annually. During the same period the commercial thinning amounted to 0.015-0.020 Mha annually, clear felling were at a high of 0.012 Mha annually (LSY, 2000).
The potential of fuel wood resources in the whole country differs according to different sources – potential of firewood is estimated as 1 Mm^3 and potential of forest logging and processing industry residues 2 Mm^3. The volume of firewood is estimated at 1.2-1.3 Mm^3 per year with a tendency to increase. Calculated logging residues alone reach 2.4 Mm^3 in Lithuania but only 0.8 Mm^3 are recommended for extraction. Small-size timber from pre-commercial thinning amounts to1.1-1.2 Mm^3 per year.
Generally wood considered as energy potentials includes:

- Small size timber – the biggest part is used as pulpwood and as pallet wood. The total supply of small size timber during the next 10 years (2001-2010) is estimated at 1.1-1.2 Mm^3/year.
- Firewood-the total supply during the next 10 years will reach 1.2-1.3 Mm^3 per year. Firewood includes part of the stems cut during the final or intermediate cuttings, tops and branches. Small stems and branches in the stands until 20 years of age stay in the forest as a natural nutrient. About 50% of the branches are purposefully collected in the final use cuttings. Other branches are left on the logging trucks and protect the soil or are spread on the cutting area.
- Cutting residues-the main and permanent source of fuel wood- the total amount of cutting residues should reach 2.4 Mm^3/year in the next 10 years, but only 1/3 can really be taken. It includes branches, tops and small stems (Baltrusaitis and Andersson, 2000).

Due to an increased final use in the private sector, the amount of cuttings residues as well as small size timber will increase.
In Lithuania the sources for forest fuel are diverse and utilization of salvage cuttings have traditionally been a key source for the production of fuel wood. Thinning and intermediate cuttings provide an additional source. In 2000 the removal of firewood in state and private forest amounted to 2.4-2.6 Mm^3. (Roser et al. 2003.)
The total net production of firewood was at a high of 2.76 Mm^3 in 1999. Lithuania imported that year 1.6 thousand m^3 and exported 0.8 thousand m^3 of firewood, changes in stocks – 66,1 thousand m^3, so gross consumption equalled 2,690 m^3 .
The consumption of fuel wood makes up 3.36 Mm^3 or 659.3 ktoe in 2002. (S. Vrubliauskas, 2001)[i] This amount consists approximately from 2.0 Mm^3 of firewood, 0.6 Mm^3 of industrial wood waste and about 0.7 Mm^3 of felling residues. (Vrubliauskas and Pedisius, 2001) The

total technical potential of fuel wood is evaluated as 845 ktoe. (S. Vrubliauskas, 2001). It means that consumption fuel wood is equal to 78% of the technical potential today.

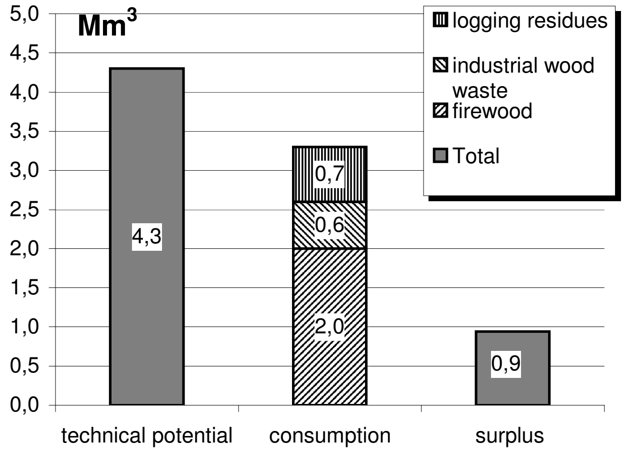


Figure 20: Potential and consumption of wood fuel (ECBREC - own estimates)

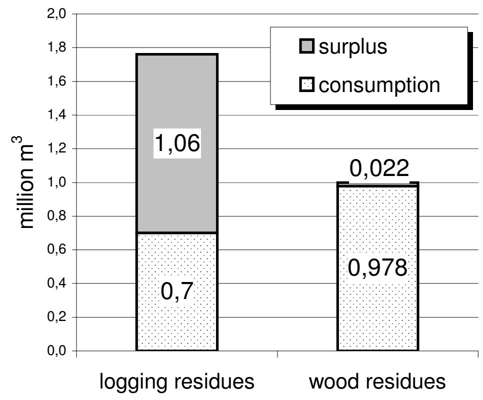


Figure 21: Production and consumption of felling residues and wood residues (ECBREC – own estimates)

According to another source (Saladis, 2003) the total fuel wood use was 3.3 Mm^3 in 2001 including firewood from the state forest (0.9 Mm^3 or 27%), firewood from the private forest (1.1 Mm^3 or 33%) and wood residues from the saw milling industry (1.3 Mm^3 or 40%).
Logging residues are not used to their full potential. The potential is significant and can possibly reach 3.3-3.5 Mm^3 if cuttings are carried out according to current policies and estimations. If logging residues would be harvested intensively another 0.8 Mm^3 could be added. The total amount of available wood fuels can reach 5 Mm^3 in the next decade (Roser and Vasikainen, 2003).
According to Kenstavičius, the amount of wood residues from felling was in the range of 1.4 Mm^3 in 1996; and according to Kuliešis, Petrauskas, it had increased to 1.76 Mm^3 in 2000 (Saladis, 2003).

Slovakia

The forest covers 2 Mha in Slovakia, which is almost 41% of the total land area and 0.37 ha per capita. Of these, about 42% are state forests and 60% non-state forests. The cooperative forests are over 50%. Others are private, municipal and church. Coniferous trees occupied 41.8% of all forests, from which the largest part is spruce, fir and pine. 58.2% is broadleaved mostly beech, oak and hornbeam. As for age structure the biggest part (21%) of Slovakian forests are 61-80 years old, a little bit less (19%) are 41-60 years old and some are 81-100 years old (18%). Total felling in 2001 was 5.98 Mm^3 of that salvage felling was 2.44 Mm^3 (FRI, 2001).
In 1999 it was almost half-half divided into coniferous (45%) and broadleaved (55%) (Beláček M. at all 2000). Today the total growing stock represents 217 m^3/ha (total volume of growing stock is 415.6 Mm^3) and growing stock per capita 77 m^3.
The annual harvesting in the region of approximately 4.5 Mm^3 is calculated for the forthcoming years; from this 3.3 Mm^3 makes wood from regeneration cuttings and 1.2 Mm^3 from tending cuttings. (FRI Zvolen, 2004). Harvesting is about 1/3 of the gross annual increment of the annual increment equalled to 15 Mm^3. The net technical potential of forest biomass was estimated at 6.7 PJ/year, the current exploited is 1.8 PJ/year so the available potential is 4.9 PJ/year (EGU, 2002). The usable amount of forest biomass is 0.93 Mm^3 (equivalent of 9 PJ) (EGU, 2002).

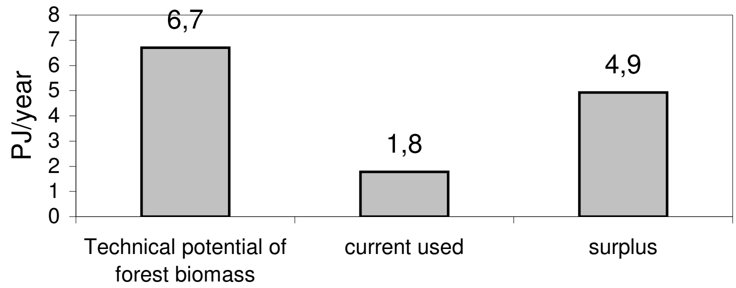


Figure 22: Potential of forest biomass in Slovakia (EGU, 2002)

In other study forest residues potentials were estimated at 6 PJ/ year, but the use in 1999 was estimated at 3.8 PJ/year. The total potential of domestic (residential) firewood equals 3PJ/ year and 2.7 PJ/year was used in 1999. (VTT, 2000)

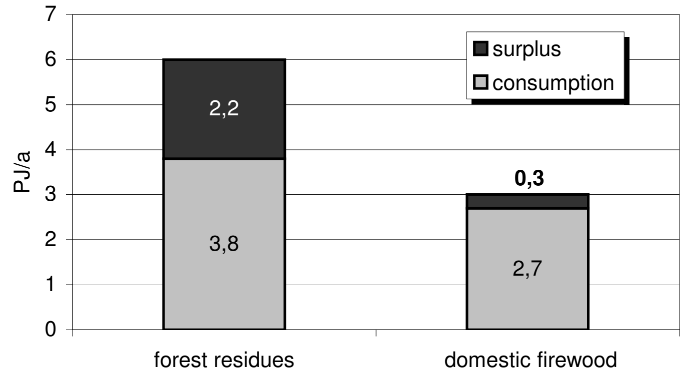


Figure 23: Technical potential of forest residues and domestic firewood (ECBREC-own estimates)

The wood consumption for heating was estimated 1.500 tons. The annual utilizable in forestry potential is 903,000 tons with an energetic value of 8.8 PJ (Beláček M. et al. 2000). Kalivrousis estimated that the biomass potential of firewood available for energy use in the short term (2000-2005) equals 3.2 PJ and of felling residues 3.7 PJ (Kalivrousis, 2000). According to another source (Kyritsis et al., 2000) the average annual applicable amount of waste in forest deposits is 4,000 t/year.

Slovenia

More than 56% of the land in Slovenia is covered with forest. A long tradition of sustainable management results in mostly mixed forests which are built mainly from spruce, beech and fir (Pogačnik, Nike 2003). 65% of the forests are in private ownership. In Slovenia for more then forty years, clear cutting has been forbidden and has been replaced by selective cutting. So, the age class distribution of forests is impossible (Sinko, 1994)

The growing stock as well as the annual increment of wood is growing steadily. This is based on the sustainable, environmentally and multifunctional use of the forests. Removals are around 2.4 Mm^3/year, which is nearly enough for wood self-supply. From the total amount of available wood, 60% is used in sawmills and paper-mills, 15% for energy and 25% for home consumption (Pogačnik, 1998).

Table 16: Structure of forests, growing stock, annual increment and felling in Slovenia in 1999 (Pogacnik, 2003)

	Structure of forests	**Growing stock**		**Annual increment**		**Felling**	**Felling in relation to annual increment**
	%	M^3	M^3/ha	M^3	M^3/ha	M^3	%
Deciduous trees	51	121.042.000	108	3.398.000	3	1.047.000	31
Coniferous trees	49	116.234.000	104	2.849.000	2,5	1.349.000	47
Total	100	237.276.000	213	6.248.000	5.5	2.396.000	38

The potentials of wood biomass in Slovenia are 0.9 Mm^3/a. In the long run we can count on $1m^3$/ha of wood biomass. An important source of wood biomass for energy purposes is thin wood from thinning in the early growing stages of forests. Most of this wood is still remaining unused in the forest, which is ecologically desired, but economically inadmissible (Robek, 1998).
There are some forest residues available in Slovenia; the yearly felling is around 21.4 PJ (Kalivrousis, 2000) from which the amount of residues is about 2.2 PJ (VTT, 2000). This report says that the biomass potential of firewood and felling residues available for energy use in the short term (2000-2005) equals 12.9 PJ.

The programmed potentials from forests, according to the national forest development programme, amounts annually up to about 0,25 Mtons (0.5 Mm^3) of wood biomass for energy, but this quantity is already used in existing individual - technological unsuitable - biomass heating systems. The annual increment of wood biomass in forests in Slovenia is 6.1 Mm^3, the average annual planned cut is 3.1 Mm^3 and the annual cut (average of 1995-1997) is 2.3 Mm^3. It is estimated that 50% of the difference between planned and realised cuts (0.4 Mm^3) may be utilised for energy purposes in the future, which makes the biomass potential from forests about 0.2 Mtons. (Robek, 1998).
The total production of fuel wood was estimated at 0.28 Mm^3 and consumption at 0.22 Mm^3. (FAO, 2004)

4.3 WOOD INDUSTRY BY-PRODUCTS

Poland

There is estimated that the wood industry produced about 7.4 Mm^3 of wood by-products. It is 27% of the total wood harvesting. The biggest quantity of wood by- products is produced in the sawmill industry. The potential of wood by-products is presented below (Ratajczak, 2002).

Table 17: Quantity of wood by-products from forest and wood industry in Poland in 2002yr (Ratajczak, 2002)

By-products	**Total [1000 m3]**	**From sawmill industry [1000 m3]**	**From wood based panels industry [1000 m3]**	**Pulp and paper industry [1000 m3]**	**Furniture industry [1000 m3]**	**Others [1000 m3]**
Particles	38031	2575	437		760	31
Sawdust and shavings	2092	1805	145		70	72
Wood dust	315		93		220	2
Bark	1190	300	280	610		
Total	7400	4680	955	610	1050	105

In the year 2001 production of industrial by-products amounted 7.4Mm^3. However, wood industry by-products were used in almost 100% of its volume: 3.8 Mm^3 by wood industry, 3.3Mm^3 for energy use, 0.4 Mm^3 for other uses. The biggest use of by-products for energy production was in the sawmill and furniture industry. Thus there exist no surplus that could be used for energy (Szostak and Ratajczak, 2002).

Czech Republic

The Czech Republic has a moderate share of the European forest sector output. The production of the forest industry is based on both chemical and mechanical processing of domestic raw material supply. A large proportion of round wood and sawn wood production is exported to Austria and Germany, respectively. Paper imports from other parts of Europe are increasing. In some studies wood industry by-products were estimated 464 ktoe (18,84 PJ) including 137 ktoe of black liquors equalled to 5.6 PJ (BTG, 2004).

Table 18: Wood residues and chips potential in Czech Republic in 2002yr (FAO, 2004)

	Units	Production	Consumption
Wood Residues	m^3	1050000	366000
Chips and particles	m^3	836	n.a

Estonia

In Estonia the wood processing industry is well developed. 95% waste wood from the wood processing processes is used for energy production, mainly as a raw material for production of wood pellets (10 000 tons in 2002) and briquettes (20 000 tons in 2000 year). The market for wood chips, briquettes and pellets is well developed and operates on a combination of contracts demand- supply basis with the price being set by the market. (Fammler et al.,2003)

Table 19: Wood residues and chips potential in Estonia in 2002yr (FAO, 2004)

	Units	**Production**	**Consumption**
Wood Residues	Cum	644,000	353,000
Chips and particles	Cum	1,592,000	n.a

Wood industry by-products potentials were estimated at 11 PJ (0.59 Mt DM). Subtracting utilization at high of 10PJ gives the number of surplus that could be used in energy 0.55PJ (IE Leipzig, 2004).

Hungary

In the year 1992, the equal of the industrial wood residues (residues, chips, particles) was as following: recovery 293 thous. m^3, export 50.6 thous. m^3, import 20.9 thous. m^3. The main tendency of utilization was as following: particle board 205 thous. m^3 and fibre board production 88 thous. M^3, a small quantity was utilised in wood chemistry and wood pulp (Halasz et al., 1992). The production and utilisation in 2002 is presented below:

Table 20: By products of wood industry (FAO, 2004)

	Units	**Production**	**Consumption**
Wood Residues	Cum	209,000	235,000
Chips and particles	Cum	166,000	n.a

The potential available of wood wastes from wood processing units equals 7.8 PJ and wastes from other resources 1.5 PJ. The potential already utilized is estimated as 5.4 PJ of wood wastes from wood processing. (Halasz et al., 1992)

Latvia

At present ‘Production of Wood and Wood Products’ is one of the biggest industrial sectors in Latvia. It is mainly oriented towards the external market. Latvian wood industry production increased twice since 1990. Part of the wood wastes (wood chips, other wood wastes) is used directly in the wood processing and furniture enterprises as a fuel for their own boiler houses. The installed capacity of the wood processing and furniture enterprise’s boiler houses using wood wastes, as fuel in 1997 was 474.6 thousand kW.
Latvian companies prepare wood-chips and export them to the EU countries. Wood for the wood chips comes mainly from the region of Cesis, sawmills included. The humidity rate of exported wood chips is up to 45%. One of the fuel types that are produced from wood waste is wood waste brick. Part of the bricks is exported to Denmark and other countries.
Production of charcoal is also ways of by-products use. Charcoal is exported or traded also in Latvia. There are sufficient resources of raw material in Latvia, which produce about 10÷20 ktons of charcoal a year. At this stage a lot of small firms are involved in this business. Private companies have started production of wood granules on a small scale. Wood pellets producers volume is today ca. 35 in Latvia. The wood pellets and briquettes production volume was 1723 kton in 2002y.

Large wood production industries use wood residues in their own boiler houses or sell them that is why wood residues are taken to the dumps only by small industries. Small sawmills and wood companies don’t sell wood residues because they have insufficient amounts to sell. (Shipkovs et al., 2004) Total amount of wood processing resides is estimated at 0.98 Mm^3 (9.8PJ). Of these 5.6PJ is already used. Thus surplus of industrual by-products that could be used for energy use equals 5.5PJ. (Shipkovs, 2004).

Lithuania
In Lithuania the total number of operating sawmills is between 600 and 800. Production of sawn timber was relatively constant at the level of 1.1-1.3 Mm^3 during the period 1995-1999. In 1999, round wood consumption in the sawmill industry was 2.6 Mm^3. Pulp and paper production was in 1999 at a very low level- only 100 ton of mechanical pulp and 9500 ton of paper were produced. However, paperboard production, increased in 1999 up to the level of 27,700 tons of round wood consumption in the wood-based panel industry was around 300,000 m^3 (MECFE, 2000)
Production of wood waste (bark, chips, sawdust) was in the range of 1.2 Mm^3 in Lithuania in 2000. The utilization of industrial residues is continuously increasing. Nevertheless, approximately 100,000 m^3 are still taken to dumps. (Roser, 2003.)
Kallivroussis estimated the potential of wood by-products from wood industry available in short term (2000-2005) equalled to 4.7 PJ. Major volume of industrial by-products is consumed (Kallivroussis, 2000).

Slovakia

Slovakia has enough forest resources to support the domestic forest industry. Nearly all of the round wood is processed in the country and production is based equally on hardwood and softwood species. The softwoods are mainly used to produce sawn wood, while the pulp industry utilizes half of the hardwood production as well as a significant amount of recovered paper and some non-wood fibre pulp.

The domestic wood-processing industry utilizes app.97% of the wood cut. The rest represents the export of assortments, which cannot be used in this country. About 2.5% of the softwood and app. 6.5% of the hardwood cut is used for production of veneers, plywood, matches and other special wood products. About 69% of the softwood and app. 36% of the hardwood cut is used in the lumber industry. About 23% of the softwood and app. 48% of the hardwood cut is used for cellulose, chipboard and fibreboard production. About 5% of the softwood and app. 9% of the hardwood cut is used for energy purposes. (FRI, 2004)

Kalivrousis estimated wood industry by-products potentials at 9.4 PJ. Of these amount 4.1 PJ is already used. Thus surplus potentials available equals to 5.3 PJ. (Kalivrousis, 2000). In other study the use industrial by-products for energy was estimated at the level 3,3 PJ in 1999 (VTT, 2000).

Slovenia

In Slovenia industrial by-products and domestic firewood are the most important biomass resources. The industrial by-product potential is estimated at 7.0 PJ/ year and domestic firewood at 8.1 PJ/ year.

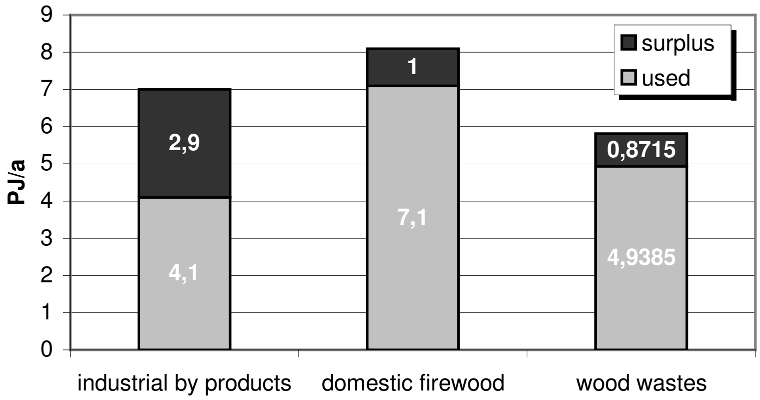


Figure 24: Potential of industrial by products, domestic firewood and wood wastes (VTT, 2000).

In Slovenia, according to some estimation, there are approximately 700,000 m^3 (5.81 PJ/ year) of wood waste per year; 50% is used for heating, 30% for recycling, 5% for composting, 15% is deposited and remains unused 4.9 PJ/y (Pogačnik, 1998). Almost all of the current firewood potential (88%) is already used in energy purposes. Of the industrial by-products, almost 60% is currently utilized. In addition small amounts of industrial black liquors (0.1 PJ) and refined wood fuels (mainly briquettes and small quantity of pellets –together 0.002 PJ/ year) are used. (VTT, 2000)

The documented quantity of wood residues in the industrial sector amounts annually to about 361,000 tons (722,000 m^3). About 230,000 tons (460,000m^3) is already used for energy purposes in existing medium sized boilers. Small companies have at least 150,000 (3,000 m^3) tons of dispersed wood residues. The additional/untapped biomass potential in the industrial sector is estimated to be at least 280,000 tons –560,000 m^3 (Robek, 1998).

Kalivrousis estimated biomass potential of wood wastes from wood processing units available for use in the short term (2000-2005) at 6.2 PJ and utilization at 2.9 PJ (Kalivrousis, 2000).

4.4 RESTRICTIONS (POLICIES AND MARKETS)

Almost all the CEE-8 countries have specific national plans for the development of renewable energy use in the future but on the other hand they are facing needs to reform the agriculture production, to extend the environment protection obligations and to follow-up forestry management rules or changes (summary presented in Table 21). Future biomass potentials in all countries will definitely be limited due to growing solid-biomass fuels use for heat and electricity production. Energy policy supporting instruments in the CEE-8 are respectively: (i) RE objectives in primary energy supply 4-12% share until the year 2010, (ii) RES electricity targets and feed-in tariffs for renewable electricity purchase from producers (iii) support for investments, (iv) acts on the increase of transportation bio-fuels production (related mainly to starch-crops EtOH and RME bio-diesel production in Czech Rep, Poland).

Forestry residues potentials (i.e. logging residues and thinning wood) might be limited due to the growing competition of wood industry and energy industry. The only country in Eastern EU, Poland has targeted plans for forestation of 0.5 Mha low-productive agricultural land. But this cannot be expected in the short-tem as a significant additional biomass potentials source. On the other hand, all the CEE-8 countries have a lower wood fellings ratio to the net annual increment of forestry wood, so we could assume an increase of wood removal in next 10-20 years. For example in Poland the current wood fellings is 27 Mm^3, which is 50% of a net annual increment of over 50 Mm^3. However forestry management rules and projections of market demand for wood removals as well as export/import balances remains unknown. Simplifying assumptions and market trends from the last decade, we can speculate growth of commercial timber wood fellings from forestry ca. 15-25% within until 2015-2020y.

Agriculture policy targets in the CEE-8 will probably not influence straw potentials limitation very much. A further decrease of the cereals sown area is expected, as well as a decrease of straw production and potentials due to intensification of production and higher yields. Agriculture policy is likely to implement or increase support for energy crops in the near future. Since 2003, CAP policy reform in the EU has implemented financial support of EUR45/ha for energy crops cultivation on agricultural land, which is not set-aside. EUR45/ha is an additional subsidy to area subsidy. In CEE-countries national subsidies for energy crops are given to farmers in the Czech Republic (since 2002) and some support in Poland is available through environmental funds. This might affect in a positive way the increase of energy crops implementation on set-aside of low-productive arable lands then.

Table 21: Summary of restrictions and policies affecting biomass resources in CEE-8

Country	Energy policy (RE targets and support) 2010y			Wood removals / potentials from forestry	Agriculture policies, agriculture changes
	RE pt	IS	FT		
Czech Rep.	4%	+	+		Support for energy-crops since 2002, decrease of cereals and straw potentials
Estonia	-	+	+	Increase for export – Northern Europe, internal use increase, limited to 20% annual increment, current removals covers80%	Decrease of cereals production 4-times set-aside land increase in decade 0,8-4% arable land
Hungary	7,2%	+	+	Increase for internal use, wood removal 5.8 Mm^3 on 60% of net increment, increased forestation planned	Decrease in permanent pastures needs Stable level of set-aside lands 4-6% of arable land
Latvia	12%	+	+	Export to Northern Europe increase, internal use increase	5% arable land set-aside, 5-times increase in decade
Lithuania	-	+		Export to Northern Europe increase, internal use increase	6% arable land set-aside, 6-times increase in decade
Poland	7%	+	Quota	Forestation program 0.5 Mha increase 2000 – 2010 expected growth of wood removals 15-25%	Support for straw use for energy (limits potentials) Set-aside lands increase from 7 to 16% of arable land (extends e-crops potential) 100% growth of maize area in last decade
Slovakia	4%	+		Mountain areas Northern Slovakia – Tetras limits wood removals and residue potentials	
Slovenia	12%	+	+	120-500 ktons residues estimated as potentials, mountains in part of country limiting extraction	Limited potentials of agricultural lands

RE pt – Renewable Energy targets in primary energy supply
IS – investment support
FT - feed-in tariffs

5. REGIONAL STUDY – NORTH (EESS LUND)

5.1 AGRICULTURE RESIDUES

Sweden, Denmark and Finland

As shown in Table 22 a large part of Denmark, over 50%, consists of arable land while arable land in Finland and Sweden accounts for less then 10% of the total land area. In all three countries, cereals are the dominant crop. In Denmark and Sweden wheat is the most widely grown grain crop while barley dominates in Finland. Among agricultural residues, straw from cereal crops has the largest potential to contribute to energy supply.

Table 22: Cereal production in Northern Europe (FAO, 2002).

	Arable land	Cereal area	Cereals share in arable land	Average yields	Total cereal production	Wheat production
	1000 ha (2002)			t/ha	1000 ton/year	
Denmark	2 282	1 531	0.7	6.0	9 150	4 563 (50 %)
Finland	2 187	1 196	0.5	3.0	3 419	449 (13 %)
Sweden	2 706	1 129	0.4	4.6	5 369	2 153 (40%)

When calculating the ratio of straw residues/grain it is assumed that all cereal crops have the same ratio. The gross ratio shows how much straw that can be removed from the fields considering “soil demands” and other restrictions. In Sweden the ratio is 0.27 if calculated for DM/ton (Börjesson 2004), while for Denmark it is 0.5 calculated for DM/ton (Danmarks statistik, 2002). Finland is assumed to have the same ratio as Sweden. It is important to notice that the Danish data are empirical and that the Swedish are theoretical ones.

Denmark has a large livestock that requires a great deal of straw for fodder and bedding etc., thus leaving less straw available for energy use. The net ratio of straw/grain in Denmark was calculated to 0.26 (Danmarks statistik, 2002) and in Sweden to 0.18. The calculation for Sweden was based on the assumption that 1/3 of the harvested straw is used for animal husbandry and other activities, which makes 2/3 available for energy use.

It is however worth mentioning that the climate in central Sweden and probably also Finland can be quite harsh in the autumns which could reduce the ratio of ton straw/grain in these areas. To some level this was taken in to account in the ratio calculations above. The straw production in the northern part of Sweden and Finland could however probably be neglected considering weather conditions and farming structure, since the cereal farms in this area is rather small and widely spread. The total amount of straw available for energy use in the northern region is shown in Table 23.

Table 23: Straw available for energy use in Northern Europe (LU, 2004)

	Gross straw/grain ratio	Net straw/grain ratio for energy	Average cereal yield	Average net straw yield	Net straw production
	t DM		t/ha	Ton DM/ha	1000 ton DM/year
Denmark	0.5	0.26	6.0	1.56	2 388
Finland	0.27	0.18	3.0	0.54	646
Sweden	0.27	0.18	4.6	0.83	937
Total					3 971

The net straw production in the northern region is 3.97 million ton/year that corresponds to 57.2 PJ. Factors limiting the straw potential are shown in Table 24.

Table 24: Factors limiting straw potentials in the northern region of Europe.

Country	Factor	Short Description
Denmark	Large livestock	High need for bedding, fodder etc.
Finland	Climate, soil and farming structure	Bad autumn weather could reduce straw harvest. Soil demand is assumed to be in level with Sweden. Small and spread farms make it more difficult and expensive to harvest straw.
Sweden	Climate, soil and farming structure	Bad autumn weather could reduce straw harvest in the north part of the country. Theoretical data shows relative high “soil demand” of straw. Small and spread farms in the north part of the country make it more difficult and expensive to harvest straw.

[a] Average 1998-2002

5.2 FORESTRY RESIDUES

The forestry potentials in the northern region of Europe are mainly concentrated in Finland and Sweden where more than 50% of the total land area is available for forestry production. In Denmark this number is approximately 10%.

Table 25: Annual gross felling and annual net increment in North Europe.

	Total land	Forest area[a]	Annual increment[b]	Annual gross felling[b]	Annual net increment[b]
	1000 ha		1000 m^{3}sk/year		
Denmark	4 310	473	4 600	1 500	3 100
Finland	30 459	20 153	83 400	73 500	9 900
Sweden	40 979	22 127	97 200	76 100	21 100
Total	75 748	42 753	185 200	151 100	34 100

[a] Available for commercial forestry production
[b] Mean value 1998-2002

In order to calculate the ratio of logging residues to stem wood, Swedish data on the residue generation of spruce, pine and broad-leaves, where used for all three countries. For this purpose the volume per hectare before felling had first to be estimated (Swedish National Board of Forestry, 2001).

It was assumed that all tree species had the same volume per hectare. This volume was set to 200 m^{3}sk for the north of Sweden and to 270 m^{3}sk for the south part. This is calculated from data given in (Swedish National Board of Forestry, 2003). Data for northern Sweden was used in the calculations for Finland and data for southern Sweden was used for Denmark. Ecological as well as technical restrictions make it however impossible to harvest all logging residues. It was therefore assumed that 70% of the spruce needles and 50% of the pine needles are left in the forest as well as 30% of the branches (Swedish National Board of Forestry, 2001). According to Swedish recommendations, biomass should only be harvested one time during the forest lifespan if the ashes aren’t recycled. In the northern countries the greatest amount of residues can be harvested at the final felling. Gross and net residue ratios for logging residues for the different tree species are shown as mass ratios in Table 26 below.

Table 26: Logging residue ratios for the two northern sub regions

		Gross ratio			Net ratio		
		Spruce	Pine	Deciduous	Spruce	Pine	Deciduous
North	Sweden	0.56	0.24	0.23	0.32	0.16	0.16

and Finland						
South Sweden and Denmark	0.46	0.20	0.28	0.26	0.13	0.15

After considering the structure of the forests in the region and to what level fellings are made in the north and south part of Sweden a gross and net ratio was calculated for coniferous and deciduous trees for each country. It is worth mentioning that the amount of residues from pine is of the same magnitude as those from deciduous trees. Consequently the result would have been more accurate if the pine and spruce potentials were estimated separately and not together as coniferous trees. The logging residue ratios fore each country are shown in Table 27.

Table 27 Gross logging residues and net logging residues in North Europe

	Annual gross felling[1] Mm^3		Logging residue ratio				Gross logging residues	Net logging residues
	Coniferous	Broad-leaf	Coniferous		Broad-leaf		Mm^3	
			Gross	Net	Gross	Net		
Denmark	0.9	0.6	0.44	0.25	0.28	0.15	0.6	0.3
Finland	59.7	13.8	0.42	0.25	0.23	0.16	28.2	17.1
Sweden	68.2	7.8	0.40	0.24	0.26	0.15	28.5	17.6
Total							57.3	35.0

[1] Average 1995-2000

If wood ashes are brought back to the forest or if fertilizers are applied, then it is possible to harvest residues from thinning operations as well. The thinning activities in Sweden correspond to 26.5 million tons in 2000 (Swedish National Board of Forestry, 2003). Assuming that the same harvest ratios for thinning residues as for logging residues gives a thinning residue potential in Sweden of approximately 6 million m^{3}sk. In Finland this number is approximately 5.5 million m^{3}sk (Hakkila, 2003). In Demark this number is approximately 0.5 million m^{3}sk assuming the same ratios as for logging residues.

In Denmark more than 50% of the residues are used for energy and other purposes while Sweden only use 10% of the residues. The amount of residues used in Finland is unknown. Most of the surplus residues in Sweden are located in the northern part of the country, which implicates potential logistic problems since the demand is mostly in the southern part of the country. With higher biomass prices it is however likely that this surplus will be used for energy purposes. In addition to the residues some felling are used directly as fuel wood. In Finland and Sweden less then 10% of the total felling are used for this purpose and in Denmark 20% are used as fuel wood

Table 28 Factors limiting the logging residue potentials in the north region of Europe.

Country	Factor	Short Description
Denmark	Nutrients	Some residues must be left in the forest or alternatively ashes must be recycled.
Finland	Nutrients and logistic problems	Some residues must be left in the forest or alternatively ashes must be recycled. North part - long distances that makes harvest difficult and cost-expensive.
Sweden	Nutrients and logistic problems	Some residues must be left in the forest or alternatively ashes must be recycled. North part - long distances that makes harvest difficult and cost-expensive.

According to P. Hakkila (P.Hakkila, 2003) in Finland technically harvestable residual biomass equals from thinning 11.9TWh which correspondents with 42.84PJ (including residues from pre-commercial thinning 2.3 TWh = 8.28 PJ and residues from 1st commercial thinning 9.6 TWh = 34.56 PJ; assumption 1MWh = 3.6 GJ) and resides from final harvest equals 8.6Mm^3, which correspondents with 59.34 PJ (assumption: 1m^3 = 6,9GJ) (IEE ALTENER ENE39/T0039/99, 1999). Other report gives the information of forest residues amount in Sweden at level of 4013 ktoe, which correspondents with 162,97 PJ (BTG, 2004).

National studies shown production of logging residues in Denmark at the level of 0.2 Mm^3 equals to 1.4 PJ (Denmark's National Statistics 2000). LR are consumed in their full potential Total production of thinning residues is estimated at 0.5 Mm^3 (3.4 PJ).

5.3 WOOD INDUSTRY BY-PRODUCTS

Both Finland and Sweden have a large forest industry, which processes domestic forest resources as well as imports round wood as well as chips and particles. About 50% of the industrial consumption of wood raw material is used in the pulp industry and 50% is used in the sawmills. In Denmark the forest industry consists of almost 100% of sawmills.

Table 29: Industrial round wood consumption and by-product ratios in Northern Europe

Industry	**Industrial round wood consumption (MM3ub)**			**By-products ratio (%)**
	Denmark	Finland	Sweden	
Sawmills	1.2	25.9	34.7	50
Plywood		3.0	0.3	60
Mechanical pulp		9.3	9.9	5
Chemical pulp		23.8	23.0	50
Total	1.2	62.0	67.9	

By-products from the forest industry consists manly of wood chips from sawmills and black liquor from the chemical pulp mills. Black liquor was however excluded in this biomass assessment. Consequently, the by-product ratio for chemical pulp production is more or less zero. The structure of the forest industry was considered when calculating the gross and net residue ratio for each country. About 70% of the sawmill by-products are used in other wood industries, mainly the pulp industry. They are therefore not available for energy use, something that was taken in to account when calculating the ratio. In the ratios shown below, bark has been included which means that the ratios were increased by 13.3 percent units.

Table 30 Industrial by-products ratios and total production in Northern Europe

	Gross ratio residues/round wood	**Net ratio residues/round wood**	**Gross residue production (Mm^{3}f)**	**Net residue production (Mm^{3}f)**
Denmark	0.63	0.15	0.8	0.2
Finland	0.38	0.21	23.7	13.0
Sweden	0.40	0.22	27.2	14.9
Total			51.7	28.1

Only the net production of the by-products is available for energy use. Currently, this surplus is used for heat and electricity production primarily in the forest industry but also in the district-heating sector.

According to VTT study total resource of wood industry by-products equals in Finland 182 PJ (including solid industrial by-products 47PJ and industrial black liquors 135PJ), surplus that could be used in energy is estimated at 0,8 PJ. In Sweden total resource amount 173 PJ (solid industrial by products 48 PJ and industrial black liquors 125 PJ) but there exist no surplus for energy purpose (VTT, 2000).

Table 31. Industrial by-products potentials, utilization and surplus in Finland and Sweden (VTT,2000)

	Solid industrial by-products		Industrial black liquors	
	potentials	utilization	potentials	utilization
Finland	47	46,4	135	134,8
Sweden	48	48	125	125

In Denmark total real production of wood industry by-products equals 0.8 Mm^3 (8PJ) according to national studies. Real utilization of these resource and possible surplus is unknown.

5.4 RESTRICTIONS (POLICIES AND MARKETS)

In the northern region there are a number of factors that could influence the amount of biomass available for BtL fuels. Most important is perhaps the current use of biomass for heat and electricity production but there is also other factors that cannot be neglected.

In Finland and Sweden, a lot of the economical available residues and forest industry by-products are used as a fuel in district heating plants and in industrial boilers. In some of these plants biomass are used for production of combined heat and power. This kind of biomass use is stimulated with taxes and, at least in Sweden, with green certificates for the produced electricity. Policies and political will make it not unlikely to assume that this kind of biomass use will increase in the future. In the southern part of Sweden most of the residue potential is used for this kind of activities but in the northern part of the country there is still a lot of residues left in the forest. This is because of long distances, which makes it more economical to import biomass instead of using the northern domestic resource. The imported biomass is partly from the eastern part of the European Union and therefore decreases the amounts of biomass available in these countries. In Denmark a large part of the straw potential is used for energy production in district heating plants and farms. In Finland and Sweden there is very limited use of straw outside the agricultural sector and competitive markets do to a large degree not affect the quantities that could be harvested and used for energy. The weather conditions, notably rainy autumns, however, will likely reduce the straw harvest. Due to the fact that the straw yields are quite low in these countries and that the cereal farms are spread over a large area it is reasonable to assume that the biomass price needs to be quite high before harvesting of straw is given priority.

Other factors that could influence the available amount of biomass are e.g. the political will to increase the area of forest nature reserves, thus reducing the area of exploitable forests and the will to maintain an open landscape, which could reduce agricultural area available for energy crops.

The most important competitive use of biomass for BtL fuels is probably the production of heat and power.

6. REGIONAL STUDY – WEST (IE LEIPZIG)

6.1 AGRICULTURE RESIDUES

Germany, France, Belgium & Luxembourg, the Netherlands

The technical potential of straw for energy in the Netherlands, Belgium and especially Luxembourg (Low countries) has little importance in comparison to France and Germany. The main reason for such large differences is based on the available agricultural land for cereal straw production. However, it is suggested that about a fourth to a third of the growing straw is not necessarily needed within the agriculture (e.g. for soil fertility – circle of nutrients) and is therefore available as a fuel. In France the technical potential of straw for energy is 17-19% of their national solid bio-fuel potentials, in Germany it corresponds to 25%. These are the maximum numbers. The gainable portion of the technical potential is more relevant because it can be used for energy purposes. It is influenced by growing and harvesting conditions as well as the geographical distribution of areas under crops and competing use of straw for animals and in the agriculture.

Table 32: Technical potential of straw for energy in Western Europe (FAO, 2002; IE, 2004)

Country	Cereals *		Cereals yields average for 1998-2002	Cereals straw	
	1000 ha	Share in arable land	t/ha	Mt /year	PJ/year
Germany	5957	0.5	6.5	8.50	122.4
France	7057	0.4	6.9	7.84	111.9
Belgium& Luxemburg	300	0.4	7.4	0.34	4.9
Netherlands	199	0.2	7.4	0.23	3.3

**wheat, barley, rye, oats*

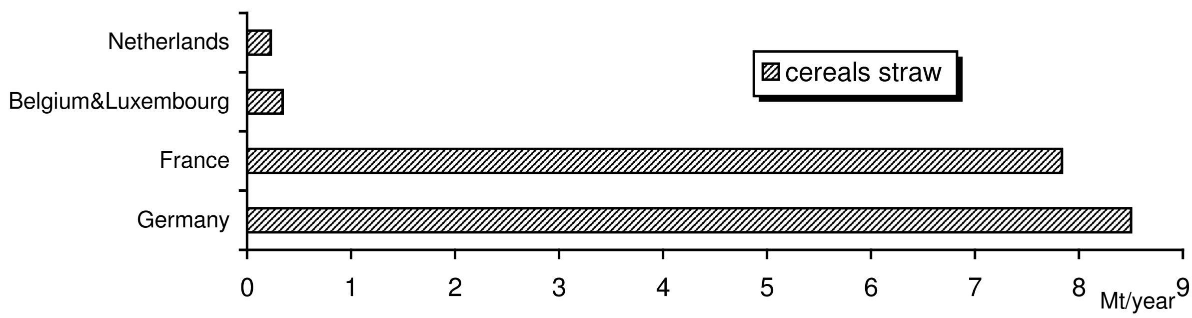


Figure 25: Technical potential for energy from straw in Western countries (IE, 2004)

The average expected straw yields are between 6.5-8 Mg/(ha*a) in GER, FR, NL and Belgium. This is about 30-45% more than in Greece, Spain or Finland. However also in Western Europe the attained straw yields range by 40% from year to year because of the different amounts of rainfalls, temperatures and geographical areas. Furthermore the high population density in these countries limits the gainable straw for energy because of the additional competitive use of straw for domestic animals and animals for leisure purposes (e.g. horses), gardening etc. Finally the technical potential of straw for energy is expected to

be about 30-50% of the total gainable straw collected from the field depending on the local conditions. This is equivalent to 160-270 PJ/ year in Western Europe, whereby GER and France have together about 50% of the gainable straw fuel potential in Europe (EU 15).
Unfortunately straw is characterised by relatively unfavourable combustion features. Therefore, there is nearly non use of straw as a fuel in Western Europe currently. At the beginning of the 80`s there existed between 100-200 small-scale straw boilers in Germany. Probably none of these plants is still in operation because of the high emission problems. At present only five relatively small straw fired pilot plants are in operation in Germany. Two of them are demonstration plants with some technical and economic problems and three boilers are used for R&D purposes (straw as co-firing fuel partly). High legal restrictions of emissions standards, still a poorly conceived technique of the straw combustion process and unattractive economic expectations limit investigations in commercial heat and/or power plants in Germany. In France and the Low countries, there are no straw fired boilers known.
Maybe a perspective of straw as fuel in Western Europe’s energy generation could be seen in straw pellets, which are used in small-scale boilers. The advantage would be that additives for better combustion features could be mixed with the straw in the pellets production process. The straw boiler technology of large-scale plants must be enhanced or straw could be used as co-firing fuel in coal power plants (<10%). Presently there is no experience with straw for biofuel production. However there seems to be an opportunity for energy grain (e.g. whole rye or Triticale plants; chapter 10.3.).

6.2 FORESTRY RESIDUES

Table 33: Technical potential for energy from wood residues from forestry (IE, 2004)

Country	Thinning residues		Logging residues		Wood residues forestry together	
	Mt DM/a	PJ/ year	Mt DM/a	PJ/ year	Mt DM/a	PJ/ year
Belgium	0.40	7.5	1.02	19.0	1.4	26.5
France	9.99	186.0	8.13	151.2	18.1	337.2
Germany	7.00	130	9.60	178.5	16.6	308.9
Luxemburg	0.06	1.1	0.03	0.6	0.1	1.7
Netherlands	0.21	4.0	0.19	3.5	0.4	7.5

Figure 26: Technical potential forestry wood residues in Mt MD/a (IE, 2004)

Germany

The area of exploitable forest in 2000 was 10.1 Mha, which had a 94.4% share of forest. It is about 28.4% of the total area.

In order to calculate an approximate value, the amount of logging residues is projected on the basis of the wooded area per country (ZMP 2003). Besides this, the gradual growth of the trees leads also to marketable wood. At present, in most of the European countries the felling of wood is each year less than the regeneration by growth. However, appropriate data to forest growth were not determined yet for most of the countries. A need for research is seen here.

The following limitations were identified (min and max were produced by different scenarios):

1. Infrastructure and forest industry structure: 0-15% reduction for small wood and 0-10% reduction for logging residues
2. Competition with other utilisation: 0-12% reduction for small wood and 0-15% reduction for logging residues
3. Sustainable forest management: 4.3-11.2% reduction for small wood and 5.7-14.7% reduction for logging residues

At the moment there is an additional high potential on round wood, which is not logged because of economic reasons (this includes about one third of the round wood potential). This additional yearly potential is round about the yearly German logging residue potential. Round wood logging in 2000 was extremely high because of storm losses (this is also true for France).

Table 34: Summary of fuel potential in Germany in 08.2003

Woody residues, by-products and wastes	Moisture%	Usable for energy Mio. t(green basis)/a	Thermo- chemical conversion Net cal. value MJ/kg_{FM}	Thermo- chemical conversion Energy carrier potential PJ/ year
Logging residues	30	13.7	12.3	169
Thinning residues	30	10.0	12.3	123
Additionally usable forest wood	30	10.7	12.3	132
Wood from landscape conservation and gardening	50	0.5	9.2	4
Wood processing industry by-products and residues	23	4.0	14.2[1]	57
Waste wood	27*	6.0	13.0	78
Total				563

*Note: according to the mass proportions of the different ranges

The technical potential for energy from forestry wood residues in Germany is estimated as: 7.00 Mt DM/a of thinning residues, 9.60 Mt DM/a of logging residues, which gives 16.6 Mt DM/a in total. About 80 biomass power plants or CHP plants have been in operation from November 2003 These plants are mainly in the range of up to 5 MW installed electrical capacity. At present, about 3.5 million tons of wood is being used in Germany each year for biomass power plants or CHP plants, the largest part being used is waste wood (85 %).

Another estimates calculated forest residues potential at the level of 142PJ. Estimates of current use showed level of 55 PJ consumed already (VTT, 2000).

France

The area of exploitable forest in 2000 was 14.6 Mha, which was 96.5 % forest. It is about 26.6% of the total area. The technical potential for energy from forestry wood residues in France is estimated as: 9.99 Mt DM/a of thinning residues, 8.13 Mt DM/a of logging residues, which gives 18.1 Mt DM/a in total.

Another estimates showed lower value of forest residues potentials (incl. thinning wood and logging residues) at the level of 38 PJ, but hose seems to be underestimated (VTT, 2000).

The Netherlands
The area of exploitable forest in 2000 was 0.314 Mha, which was 92.6% forest. It is about 9.26% of the total area. The technical potential for energy from forestry wood residues in The Netherlands is estimated as: 0.21 Mt DM/a of thinning residues, 0.19 Mt DM/a of logging residues, which gives 0.4 Mt DM/a in total.

Belgium & Luxembourg
The area of exploitable forest in 2000 was 0.725 Mha, which was 99% forest. It is about 22% of the total area. The technical potential for energy from forestry wood residues in Luxembourg is estimated as: 0.06 Mt DM/a of thinning residues, 0.03 Mt MD/a of logging residues, which gives 0.1 Mt DM/a in total. The technical potential for energy from forestry wood residues in Belgium is estimated as: 0.40 Mt DM/a of thinning residues, 1.02 Mt DM/a of logging residues, which gives 1.4 Mt DM/a in total.

6.3 WOOD INDUSTRY BY-PRODUCTS

Germany
The potential of industrial wood residues in the sector of sawmills can be derived from the statistics about felling and about lumber production with regard to the specific losses. Since specific data are not present yet for all European countries, for countries with an insecure database, the wood felling statistics combined with data about foreign trade with wood are used as an orientation value. Starting with the wood felling statistics in the last available year of reference (2001 or 2002, depending on the country) the import of raw wood is added and the export of raw wood subtracted [FAO]. From this amount the results of quantity of processed wood in the respective inland can be determined. The quantity of industrial wood residues is deducted from this as an orientation value. The result is dominated by Sweden and Finland with the extensive wood processing industries while Germany follows on in third place. The biggest part of the mentioned potentials is already used today, partly for the heat production, partly materially for the chipboard production. Thus it is already foreseeable that the technical potentials specified here represent no accessible potentials. The technical potential for energy from wood processing in Germany is estimated as: 57 PJ/ year of industry residues.

France
The technical potential for energy from wood processing in France is estimated as: 47.3 PJ/ year of industry residues (IE, 2004). In other study utilization of industry residues was estimated at the level of 8.3PJ (VTT, 2000). Thus, hypothetic surplus market of by-products that could be used for energy equals 39.2 PJ.

The Netherlands
The technical potential for energy from wood processing in The Netherlands is estimated as: 1.2 PJ/year of industry residues (IE, 2004).

Belgium
The technical potential for energy from wood processing in Belgium is estimated as: 8.8 PJ/ year of industry residues (IE, 2004).

Luxembourg
The technical potential for energy from wood processing in Luxembourg is estimated as: 1.2 PJ/ year of industry residues (IE, 2004)

6.4 OTHERS

The production of cereals for combustion or for fermentation may be done like for production for food or fodder use. For fermentation use high grain yields must be obtained, while for combustion a high total yield is aimed at, as both grain and straw are used. In Germany wheat, triticale and rye are investigated. Wheat has the highest yield potential on good soils, while rye produces better on poor soils. Triticale performs intermediate and attracts interest for energy purpose, as it is not used for food production. A mean total yield of 12 t/ha (5.5 t/ha of grain) dry matter is expected under German conditions. In France total yields of about 10-14 t/ha (dry matter) were obtained.
Cereals are highly developed crops due to their use for food production, and the knowledge of production is widespread among farmers. Therefore, energy grain production can easily be implemented in agriculture and high and stable yields can be expected. The production fits into standard crop production. The production is flexible as only planning for one year at a time is necessary. Grain loss during harvest is related to the harvest time. Energy grain production is most often not profitable given the current market price of biomass for energy. Further cost reduction is improbable as the production is already optimised. In Denmark a 50% reduction of Cl in the straw fraction was obtained by using chloride free fertilizer.

6.5 RESTRICTIONS (POLICIES AND MARKETS)

In the Western Europe it's expected further increase of solid biomass resources use for heat and electricity production until 2010 year, therefore also it affect biomass potentials volume available in the region. Targets of renewable electricity production summarised in Table 35 and support incentives s.a. (i) investment support for bio-energy heat production or (ii) feed-in tariffs or obligation quotas for electricity purchase from renewable resources will affect decrease of biomass residues potentials. In short-run until 2010y we may expect significant increase of forestry residues and wood-industry by-products supply for energy. Straw increase use depends strongly from national and regional policies and not every country in Western Europe supports straw use for energy.

Table 35 Summary of renewable energy production targets and support incentives that affect biomass potentials volumes until 2010y in Western Europe.

RES targets	**Belgium**	**Germany**	**France**	**Lux**	**The Netherlands**
RES share of gross electricity consumption in 1997 [%] **RES-guide line** (2001/77/EC)	1,1	4,5	15,0	2,1	3,5
2010 (indicative target) [%]	6,0	12,5	21,0	5,7	9,0
EU-Biofuel target in % (2003/30/EC)					
Share of biofuels and other renewable fuels in 2005	2,0	2,0	2,0	2,0	2,0
Biofuel as additive to conventional fuels (gasoline, Diesel) in 2010	5,75	5,75	5,75	5,75	5,75
Policy incentives supporting bio-energy					
Investment support for heat & electricity	x	x	x	x	x
Tax advantages	x				x
Feed-in tariffs for electricity	x	x	x	x	x
Allocation of quotas / certificates of "green electricity"	x				

7. REGIONAL STUDY – IRELAND AND UK (NU_DUBLIN)

7.1 AGRICULTURE RESIDUES

Table 36 Cereals straw potential for energy in Ireland and the UK (FAO 2002; UCD, 2004)

Country	Cereals *		Cereals yields for 1998-2002	Cereals straw production	Cereal straw for energy
	1000 ha	Share in arable land	t/ha	Mt /year	Mt /year
Ireland	320	0.8	7.2	1.46	0.53
The UK	3150	0.7	6.9	14.4	7.7

* wheat, barley rye, oats

Ireland

In 2000 there were 0.4 million ha of arable land (9% of agricultural land). Cereals account for approximately 80% of arable land; the rest is used for potatoes, turnips, beet, vegetables, arable silage and maize for ensilage. The cereal crops grown are barley, wheat and oats. Barley is the dominant crop (44% of arable land). All maize planted is ensiled with none used for grain production. According to a Sustainable Energy Ireland report in 2004 straw residue presently amounts to between 1.2 and 1.46 million tons with a surplus ranging from 0.08-0.53 million tons depending on seasonal factors.

Cereal production is concentrated in the east and south. Animal bedding accounts for 70% of straw use, a further 22% is ploughed back into the land and 8% goes to mushroom compost; other uses are minimal less than 1%. The 22% ploughed back into the ground is what is considered potentially available for energy production.

The United Kingdom

In 2002 there were 4.5 million ha of arable land (25% of agricultural land), 0.57 million ha is fallow, the rest is sown. Cereals account for approximately 70% of arable land; the rest is used for potatoes, turnips, beet, vegetables, arable silage and maize for ensilage. The cereal crops grown are barley, wheat and oats. Wheat is the dominant crop accounting for 60% of the cereal area. Maize cultivated in the U.K is ensiled and feed to cattle.

In England the cereal production is concentrated in the south, East Anglia, Yorkshire and the East Midlands. Many of these areas have a lot of tillage land and not a lot of animals so that is where most of the straw surplus exists. Applying the average cereal yield of 6.5 t/ha to the sown area gives a grain harvest of 22.2 million tons for the U.K. Using the 65% ratio this gives 14.4 million tons of straw. About 6.7 million tons is needed for animal and mushroom production, thus 7.7 million tons are left as an unwanted by-product. Most of this is currently chopped by the combine and returned to the soil. This is where we would see potential for utilizing straw for energy production.

In the U.K there are already a number of energy companies such as the Ely Power plant, which exploit the straw reserves of Cambridgeshire in East Anglia for electricity generation.

7.2 FORESTRY RESIDUES

Ireland

The Forestry Service of Ireland quotes an area of 0.689 Mha of available forestry. Only 2% is unavailable for harvest which is a low percentage compared to the rest of Europe. This is

probably due to the fact that Ireland was virtually striped of all of its forests in 1900 with only 0.100 Mha of the woodland left intact. Most of the forestry has therefore been planted in the last hundred years and was planted with a view to harvest with modern harvesting practices. Also grants that became available in the 1980's encouraged large amounts of commercial planting. Coniferous species are the most important with Sitka Spruce being the dominant variety. The current national increment is unavailable but calculated on a pro rata basis from U.K figures it works out at 6.1 Mm^3sk.
Most deciduous harvesting is done on a small scale so figures for residues are very hard to obtain but are not thought to be significant. Much of the residues from final harvesting such as tops and branches are needed to make a brash layer or road. This helps protect the soil structure of the forest, which is often quite delicate.
There has been a recent surge in private planting, which now accounts for over 80% of planting. There will be an associated rise in the thinning activity between 2012 and 2015. Currently there is no sufficient market to meet this projected supply. COFORD - the national council for forestry research and development is worried that if a market is not forthcoming growers will avoid thinning because it is too costly and this may cause a drop in the quality of the end harvest. According to national studies in Ireland there are produced some amounts of logging residues– it is about 0.3 Mm^3 (2.1PJ) and of thinning residues – 0.6 Mm^3 (4.14 PJ).

<u>The United Kingdom</u>
The British Forestry Commission gives an exploitable area of 2.4 Mha. This is approximately 85% of the total forestry lands. Forestry planted on nature reserves and national parks in Britain will be available for commercial harvest. Much of the trees considered unavailable for harvest would be from large estates where they are used as cover for recreational hunting and other leisure activities. Figures for deciduous residues were considered to be insignificant.
The forestry commission gives a figure of 21.2 Mm^3sk for the annual increment. This is much higher than the FAO figure. Coniferous varieties account for 80% of this growth. Spruce varieties are the most important.
New planting in Britain has been falling off since the 1970's when it was at 40,000 ha per annum; currently it stands at 12,300 ha per annum and is not expected to return to such high figures in the coming years.
National studies shown that total production of logging residues in the UK equals 1.6 Mm^3 (11.04 PJ) and of thinning residues 3.8 Mm^3 (26.22 PJ) Amount of logging residues was calculated based on the difference between "fellings" and "removals" in TBFRA 2000 (data for 1995). The difference between "fellings" and "removals" was shown as 1.3 Mm^3 overbark conifers and 0.3 Mm^3 overbark broadleaves.

7.3 WOOD INDUSTRY BY-PRODUCTS

<u>Ireland and the UK</u>
With regard to timber production in Ireland, there are several streams of wood waste material. Firstly, the stripped bark is used as a horticultural material and there is sufficient demand for this material such that currently it is not available for energy production
Secondly, saw dust / chippings from timber processing – this material is being used for heat and energy production internally in the sawmill industry. The material is either burnt directly for heat production in a boiler or is used as a fuel for a CHP plant on site. Any remaining material is used in the laminate board sector.

Thirdly, off-cuts and waste wood – this material has been harder to handle due to the possibility of some of it being treated with preservatives etc. Where the wood can be separated prior to preservative treatment, it is recovered into either the laminate sector or the fibreboard sector. However, if the wood has been treated – recovery options are limited to mulching for green cover or use in a composting situation. There is an on-going study in Ireland to look at the recovery of waste wood but it is not completed yet.

According to VTT study on biomass potentials in Ireland and UK exist some surplus of unused industrial by products that could be used in energy. In Ireland production of industrial by-products equals 7.2 PJ and consumption 2.5 PJ. Thus surplus equals 4.7 PJ. In the UK production of industrial by products equals 12 PJ, utilization 11.4 PJ and surplus 0.6 PJ (VTT, 2000).

7.4 OTHERS

Ireland and the UK

There are two potential biomass supplies in both Ireland and the U.K not mentioned in the report. These are sugar beet residue and spent mushroom compost. Spent mushroom compost is a by-product of the mushroom industry. It is composed of roughly 20% wheat straw. It has high moisture content and thus a high transport cost that could prove detrimental. To counteract this, most of the mushroom industry is concentrated in a small area so transport distance may not be too long. In 2000, S.M.C production for Ireland totalled 295,000 tons with a larger figure expected for the U.K.

Sugar beet residues are comprised of beet tops and leaves left over from current harvesting methods. Preliminary results based on work by Bernard Rice of Teagasc estimate the resource to amount to 1,419,600 tons in the U.K and 264,200 tons in Ireland. However there is currently no satisfactory way of harvesting the beet tops without slowing down the main work of collecting the roots.

7.5 RETRICTIONS (POLICIES AND MARKETS)

Ireland

Policies

Sustainable Energy Ireland, formerly the Irish Energy Centre, is Ireland's national energy authority. The Authority, which was established on May 1st under the Sustainable Energy Act 2002, promotes and assists environmentally and economically sustainable production, supply and use of energy. Its remit relates mainly to improving energy efficiency, advancing the development and competitive deployment of renewable sources of energy and combined heat and power, and reducing the environmental impact of energy production and use, particularly in respect of greenhouse gas emissions. The Authority is charged with implementing significant aspects of the Green Paper on Sustainable Energy and the National Climate Change Strategy as provided for in the National Development Plan. Sustainable Energy Ireland manages programmes aimed at:

- assisting deployment of superior energy technologies in each sector as required
- raising awareness and providing information, advice and publicity on best practice
- stimulating research, development and demonstration (RD&D)
- stimulating preparation of necessary standards and codes
- publishing statistics and projections on sustainable energy and achievement of targets.

Sustainable Energy Ireland is organised into five divisions and operates from offices in Dublin, Cork and Sligo.

Industry and Public Sector

The Industry and Public Sector unit will assist in reducing the energy intensity of the industrial, commercial and public sectors. The main drivers towards sustainable energy will be economic instruments, negotiated agreements, and best practice promotional activities. These drivers will influence the market failure categories of under-priced carbon dioxide emissions and cost barriers. Sustainable Energy Ireland's programmes will help to address these issues through provision of information, demonstration, verification, certification and benchmarking, and RD&D support.

Consumer Awareness

The Consumer Awareness team will apply measures to transform consumer markets in favour of greater energy efficiency. Its programmes target the residential sector, private motorists and schools. Activities will apply to both demand and supply sides of the market, and extend from standards and certification to information provision and service development. These include direct market interventions in the areas of Home Energy Rating and low-income housing, allied to RD&D.

Research, Development & Demonstration (RD&D)

The aim of the RD&D Programme is to generate results from funded projects leading to more sustainable energy practices and policies in Ireland. Such results can be in the form of improved technologies, products, processes, practices and policies aimed at impacting in the market. These may also lead to new business opportunities for sustainable energy products and services in home and export markets. Support under the programme will be available to a wide range of proposal types – including policy studies, field research, feasibility studies and technology research, development and demonstration. The Authority is also responsible for promoting, and co-ordinating with, relevant EU and international RD&D programmes.

Sustainable Energy Services

The Sustainable Energy Services team aims to promote the supply of electrical and transport energy services on a sustainable basis. In particular, it will stimulate the development and deployment of renewable energy with a target of 500MW new electricity from renewable by 2005 and combined heat and power with a target of 0.25MTC savings. This will be achieved by fiscal measures to stimulate the market, investment in infrastructure, a research and development programme and provision of information and advice. The team will also act as a focus for RD&D and associated activities in the transport sector

8. REGIONAL STUDY – SOUTH (CRES)

8.1 AGRICULTURE RESIDUES

In the Southern Europe the agricultural residues potential for energy includes cereals straw, maize residues and permanent crops residues such as olive tree pruning, fruit tree pruning and grape pruning.
The cereals straw potential was calculated with the 0.9 grain/straw ratio. Then, the assumption that 20% of straw harvested is available for energy was applied (Panoutsou, 2004a).

Table 37: Straw potential for energy in the Southern Europe (FAO, 2002; CRES, 2004)

Country	Cereals *	Cereals yields for 1998-2002	Grain	Straw harvested	Straw for energy
	1000 ha	**t/ha**	**Mt/year**	**Mt /year**	**Mt/year**
Greece	1020	2.3	4.23	3.81	0.76
Italy	2963	3.2	20.62	18.56	3.71
Portugal	365	1.2	1.62	1.46	0.29
Spain	6109	2.6	24.63	22.16	4.43

* wheat, barley rye, oats

As for olive and fruit trees prunings as well as grapevines a large part of them is used for energy purposes in rural areas. Large stems of the olive-oil trees have already a high market demand since they are used in stoves and chimneys and they are sold at high prices. Therefore, there are no available quantities for further energy exploitation. The remaining quantity of small branches and leaves are partly utilized for energy purposes by the olive-oil owners and rarely for feeding goats and sheep. However, the large majority of them remain unused and farmers in order to clean their fields burn them in the field. A large part of grapevines production is used for home energy uses in rural areas. The rest of it is burned out in the fields (Dalianis and Panoutsou, 1998).

It was assumed that 20% availability of straw as well as vines and olives prunings for energy purposes in a good scenario for the Southern countries (Panoutsou, 2004b) and this was presented in the RENEW biomass potentials calculations. However, below there is an overview of results of existing biomass potential assessment studies.

Greece

The quantities of agricultural residues were estimated using data from the Annual Agricultural Statistics for the years 1996-1998 (NSS a). Additionally, the ratios of residue quantity to product yield and the moisture content of each type of residue were derived from literature (Apostolakis et al., 1987) – see Table 38 . The theoretically available quantities were assessed taking into account the percentages already used. From the total agricultural residues produced in Greece, a part is already exploited and used in several energy and non-energy markets. Cereal straw is used for various purposes such as animal feeding and animal bedding. There is also a greenhouse in northern Greece using straw for heat production. Therefore Voivontas assumed that 15% is available for bio-energy applications (Voivontas et al., 2001). In the case of rice straw, cotton and corn stalks and corncobs, although no alternative markets have been reported, the availability percentage was set to 60% due to difficulties in harvesting and handling. Olive pruning (especially the large stems) are used in stoves and fireplaces for residential heating and their availability was set to 50%, while pruning from vines and other types of trees are not preferred for this purpose and it was assumed that 80% are available for bio-energy applications (Alexopoulou et al., 1999).

Table 38: Characteristics of crop residues in Greece (Apostolakis et al., 1987)

Residue	**Product /Residue ratio**	**Moisture (%)**	**Higher Heating Value (MJ/kg)**	**Cultivated area (ha)**	**Available quantities (dry tons/year)**
Durum wheat straw	1.00	15	17.9	245,019	80,415
Soft wheat straw	1.00	15	17.9	612,047	184,378
Rice straw	1.00	25	16.7	27,982	94,320
Barley straw	1.24	15	17.5	144,884	35,741
Oats straw	1.27	15	17.4	43,853	8,307
Corn cobs	3.75	50	18.4	213,181	165,694
Corn stalks	1.42	60	18.5		350,059
Sunflower straw	0.50	40	14.2	26,818	28,603
Cotton stalks	0.50	45	18.2	412,727	877,809
Sugar beet leaves	2.51	75	14.6	42,585	123,084
Tobacco stems	0.91	85	16.1	67,070	14,260
Vineyard prunings	1.20	40	18.3	133,408	364,471
Olive prunings	0.98	35	18.1	749,522	881,314
Peach prunings	2.51	40	19.4	45,993	121,383
Pear prunings	1.26	40	18.0	4,213	30,727
Apple prunings	1.20	40	17.8	14,874	139,080
Apricot prunings	2.84	40	19.3	5,047	7,864
Lemon prunings	2.22	40	17.6	11,917	39,207
Orange prunings	2.90	40	17.6	40,050	152,404
Cherry prunings	1.20	40	19.1	8,613	19,404
Tangerine prunings	1.55	40	17.6	6,137	22,864
Almond prunings	0.28	40	18.4	23,613	83,921
Total				**2,789,553**	**3,825,309**

Based on the above it was estimated that app. 3.8 million dry tons of field crop and arboriculture residues are theoretically available for energy production with a total energy potential of 69 PJ/year.

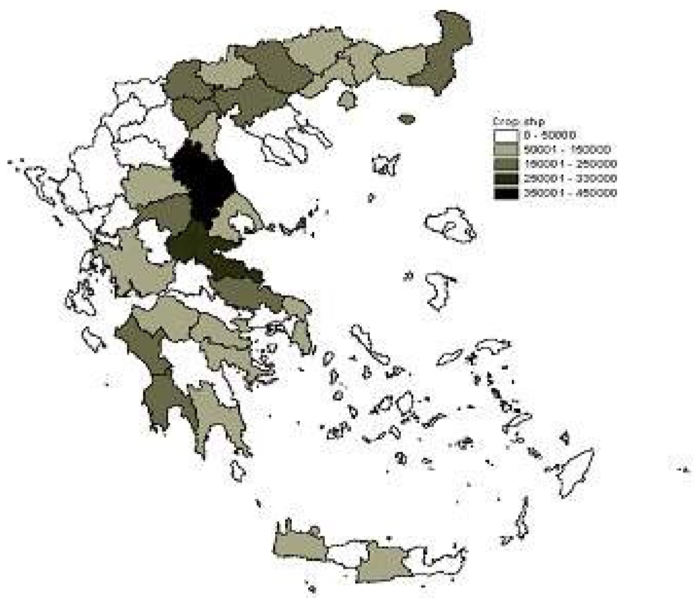


Figure 27: Geographic distribution of the available quantities of agricultural residues in Greece.

The main volume of the field crop residues are either incorporated into the soil or burned on the field, although there are sufficient quantities of residues in the country.

Italy

Dalianis and Panoutsou (Dalianis and Panoutsou, 1998) have estimated the production of agricultural residues in Italy: 5.5 Mt of corn residues, 9 Mt of small grain cereals straw, more than 3 Mt of olive tree pruning and 1 Mt of grape pruning. The Table 39 presents potential of permanent crops residues according to ALTENER project estimations:

Table 39: *Permanent crops residues potential in Italy (ALTENER 4/1030/C/00-022/2000, Final Report)*

	Available for energy (dry tons/ year)
Citrus trees pruning	120 000
Fruit trees pruning	320 000
Grapes pruning	688 000
Olive trees pruning	437 000
Total	1 565 000

Portugal

Dalianis and Panoutsou (Dalianis and Panoutsou, 1998) have estimated the production of agricultural residues in Portugal: 14 Mt of small grain cereals straw, 1.2 Mt of corn residues, 1 Mt of olive tree pruning and 0.2 Mt of grape pruning. The Table 40 presents potential of permanent crops residues according to ALTENER project estimations.

Table 40: *Permanent crops residues potential in Portugal (ALTENER 4/1030/C/00-022/2000, Final Report)*

	Available for energy (dry tons/ year)
Citrus trees pruning	41 000
Fruit trees pruning	195 000
Grapes pruning	294 000
Olive trees pruning	74 000
Total	604 000

Spain

Dalianis and Panoutsou (Dalianis C. & Panoutsou C., 1998) have estimated the production of agricultural residues in Spain: 15 Mt of small grain cereals straw, 1 Mt of corn residues, 6.5 Mt of olive tree pruning and 1.2 Mt of grape pruning.

Another source provides that farm wood residues in Spain were estimated at 331.5 ktoe (850 000 ha x 0.39 toe/ha) (IDAE, 1999).

8.2 FORESTRY RESIDUES

Greece

The total forests area in Greece equals 3.4 mill ha; it is 52% of the country area. The major portion of forests is composed of sub-selection and selection stands while the remaining is of even-aged stands. The stand structure appears as one-storied, two-storied and multi-storied. Forests managed as coppice totally consist of even-aged stands. The length of rotation of these coppice forests is 25-35 years, depending on the site, the climatic zone, and the species growing on the particular site. The main products of this type of forest are fuel wood and charcoal.

Forest management in Greece is characterised as especially difficult, since the wooded areas are sited in mountainous or remote regions with adverse pedo-climatic conditions, such as poor and thin soil as well as drought.

The mean growing stock of Greek industrial forests amount up to 45.2 m3/ha and is composed of conifers (56% of the total growing stock) and broadleaved species (44% of the total growing stock). It is compared to the mean growing stock of other European countries, is considered as relatively low. This figure does not indicate the real state of Greek forests, because there are many forest complexes which are well-organized and managed for a long time which support stands with a mean growing stock, ranging from 350 to 400 m3/ha. In particularly, the growing stock amounts to 19 m^3/ha in pine forests, 76 m^3/ha in fir forests, 84 m3/ha in beech forests, 19 m3/ha in oak forests and 35 m3/ha in forests covered by other broadleaved species (ash, hop hornbeam, plane-tree, elm-tree etc). The mean growing stock of the Greek non-industrial forests amount up to 1 m3/ha. The mean growing stock has decreased significantly because a high percentage of forests are coppice or over-thinned due mainly to human actions of the past.

Greece has a rather small forest sector and a large share of its round wood production is used as fuel. The wood of large dimensions is no more than fifty to sixty percent of the total volume harvested from forests producing such wood. The rest is wood of small dimensions, tops, branches and wood of low quality. While hardwoods are used mainly for energy purposes, the softwoods are processed into sawn wood and particleboard. The country imports all types of forest products, especially sawn wood and paper products.

Concerning logging residues, in forestry practice large amounts arise during the harvesting operations (in the form of bark, tops, branches, leaves and needles) and are left behind in the forest terrain. The potential of logging residues in Greece is roughly estimated at 1.7 Mtons (including stumps and roots), but only a part of them could be utilised for energy purposes after the introduction of modern harvesting technology (rough estimation ~ 400,000 tons). Both the state forest managers and the particleboard industry have encouraged removal of logging residues for many reasons such as:

- providing raw material for the particleboard industry,
- avoiding accumulation of biomass on the forest floor and reducing forest fire risk,
- making room for reforesting and facilitating access during forest operations, as well as
- ensuring the forest is healthy by avoiding fungi and insect attacks.

The existence of steep slopes, the lack of mechanisation in harvesting operations (horses and mules are the standard form of power used to skid logs from the stump to the forest road) and the inefficient legal framework that regulates the system of forest exploitation through forest co-operatives, are the main reasons for not utilising forest residues.

Energy potential of forest residues in 2000 year was evaluated at 1.78 PJ (Nikolaou, 2003)

Italy
Because of its long north-south extension and range of altitudes, Italy possesses a large variety of forest types and of flora and fauna. The potential of forestry biomass resources is quite high; in fact, forest area is 10 million of ha and nearly 1 million ha of other wooded land. Italy has the largest area of the forest in the sub-region after Spain. However less then 2% of such a land is used for wood production. Predominantly broad-leaved stands make up more than 70 percent of the forest area, of which about half is coppice and coppice with standards. As elsewhere in the Mediterranean area, forest fires are an annual hazard. With 0.2 ha per capita, Italy has the lowest forest area per inhabitant among the countries of the region. EU research study estimated wood residues potentials of 4.7 Mtoe (191 PJ) (ERA Bioenergy, 2002 - presentation) but this seems overestimated. According to another study on biomass potentials (BTG, 2004) production of logging and thinning residues is at high 370 ktoe (15 PJ).

Portugal
Forest occupies 3.2 Mha (Pine 1.15 Mha, Eucalyptus 0.65 Mha, cork oak 1.2 Mha and other species 0.2 Mha in Portugal. Yearly potential of wood felling was estimated at 0.6Mtons pine-wood 0.65 Mtons Eucalyptus (ERA Bioenergy 2002). Logging residue and thinning residues potentials were estimated 20.47 PJ (BTG, 2004).

Spain
Spain has the largest forest area in the region, with 14.4 million hectares or more than one-quarter of the total. It has a further 12.5 million hectares of other wooded land, so that forest and other wooded land accounts for about half the country's land area. The area of forest has been expanding strongly as a result of planting and conversion of other wooded land to forest, despite setbacks due to forest fires. More than two-fifths of the forest area is predominantly coniferous, with a further one-fifth mixed coniferous/broad-leaved. The strongest growth occurs in the maritime and radiata pine and eucalyptus stands in the northern part of Spain, where a large part of wood production also takes place. Elsewhere, forest serves an important soil protection function. About one-quarter of the forest area is not available for wood supply, mainly for reasons of conservation and protection. VTT estimates showed forest residues potentials of 58.5 PJ in Spain (VTT, 2000).

Romania
Forest covers 6,448 million. ha which is 28.0% of total country land. (FAO, 2004) Norway spruce is the principal coniferous species, which occupied in 2000 only 30% of forests. The main broad-leaved are beech and oak and they cover 70% of forests area. About 89% of the forest is available for wood supply and an even higher proportion is semi-natural forest, with only small areas of forest undisturbed by man and of plantations.
Ownership of the forests was formerly entirely by the State (94% of forest area), but the process of privatization and restitution is leading to an increase in private ownership. The age class structure of the forests is oriented towards the middle-aged stands.
Net increment, which is above the European average, has exceeded felling by a considerable margin for some decades, leading to an expansion of growing stock. 61% of the volume of total growing stock (which equals 1341.465 Mm^3) is comprised of broadleaved species. Proportion of net annual increment is similar: 65% of total net annual increment (which equals 31.878Mm^3) is produced by broad-leaved. (TBFRA, 2000) Annual felling at high of 13.600Mm^3 is 42.6% of net increment.
According to previous studies potential of firewood available for energy use in short term (2000-2005) equals 19.8 PJ. (Kallivroussis, 2000). However latest studies showed number of

wood fuel and forest residues potential at high 109.9PJ. Almost all that amount is already used in Romania (Nikolaou . et al,2003).

Bulgaria

Forest and other wooded land covers 3.69 million ha, which is for over a third of the land area (33.4%) (FAO, 2004), a proportion which is increasing as a result of afforestation, intended chiefly for soil protection, rather than wood production, and to correct forest degradation in earlier years. Plantations account for more than a quarter of the forest area, most of the remainder being classified as semi-natural. There is a small area of forest undisturbed by man. The major part of the forest area is available for wood supply - 87% (TBFRA, 2000). The areas not available are increasing, partly at the expense of areas available for wood supply and partly as a result of afforestation.
All forests were State-owned until the restitution process began in 1999; ownership by municipalities and private individuals is expected to gradually increase. It is expected that the ownership pattern after the restitution process will be as follows: 33% state, 50% municipal and 17% privately owned. Protected nature reserves and forests with a special regime of management constitute more than 30 percent of the total forest area. As for age structure the biggest part of forest in Bulgaria is 21-40 years old.
The main coniferous species are Scots and Austrian pine and Norway spruce. Coniferous trees cover 22% of forest area. However dominate broadleaved (mainly beech and oak), which occupied 68% of total forest area and mixed forest only 10% in 2000.
Today growing stock equals 467345 thous.m^3 and net annual increment 11972.4 thous.m^3. Total fellings are 40% of net annual increment, which correspondent with 4851.8 thous.m^3. (TBFRA, 2000) There has been an impressive increase in growing stock in recent decades, as a result of regeneration, afforestation and a cautious utilization policy.
to latest evaluating amount of forest residues (including logging and thinning residues) equals 4.104PJ and they are not utilized, but some studies showed higher potential at the range of 47.8 PJ/yr including forest residues and fuelwood. (BTG, 2004).

8.3 WOOD INDUSTRY BY-PRODUCTS

Greece

It is estimated that about 50% of wood processing residues are consumed either as raw material in the particle board industry either as fuel by the industries themselves to cover their own heat demands. Unfortunately no any up to date accurate survey has been carried out in the wood industry sector, regarding reuse of wood residues. Fifty wood processing industries (processing imported wood also) use wood residues for energy production by themselves (to produce steam for heating, drying and steaming). The consumption of residential wood for energy purposes amounts to approximately 90-100 ktons. The available wood processing residues are sparsely distributed around Greece.
Wood industry in Greece produce by products, which energy potential was estimated at 10.3PJ (BTG, 2004) or 11.3 PJ (Nikolaou, 2003).

Italy

Italy is a major net importer of primary wood products (although a large exporter of furniture)
According to VTT estimates (VTT, 2000) total production of wood industrial by products equals 36 PJ/a. BTG (BTG, 2004) confirm this assessment and give the figure of 36.7 PJ (35PJ of solid industrial by products and 1.7 of black liquor). Other potentials estimates of

industrial residues available in 2000 resulted in 42.9 PJ including dry lingo-cellulosic (36 PJ), wet cellulosic (5.22PJ) and industrial black liquor (1.77 PJ) (Nikolaou A 2003).

Portugal

Portugal has extensive areas of cork oak and is the world's leading producer and exporter of cork products. It is also an important net exporter of wood products. Pulp and paper industry is one of the most important industries in Portugal. The largest concern is Portucel, itself one of the most important companies in Europe, in the field, comprising two pulp factories (Cacia and Setubal) and one paper factory (Setubal). Soporcel (at Figueira) has been recently acquired by Portucel and its annual paper production is 730 ktons/year. (ERA Bioenergy, 2002)

Estimates of by-products potentials (VTT, 2000) gives by-products production at level of 49,4 PJ (including solid industrial by-products 27 PJ and black liquors 22PJ). Utilization was estimated as 42.6 PJ. Thus surplus available for energy use can be estimated 6.8 PJ.

Spain

Pulp and paper sector in Spain is intensively utilising by-products (black liquors and debarking residues) in own CHP plants, covering 70% of energy needs in sector. About 70% of the wood-industry by-products are utilised for energy purposes (i.e. wood drying) in sawmill sector. By-products potentials in Spain were estimated as 1.6 Mtoe (65 PJ) and utilization 1.3 Mtoe (53 PJ). Estimated surplus market equals 12PJ.(ERA Bioenergy, 2002)

Romania

Romanian forests provide sufficient raw material resources for the domestic industry and also for exports. While over half of the sawn softwood production is exported, the hardwoods are further processed into more value-added products such as parquet, solid wood panels and furniture. The paper production is not sufficient to supply the domestic demand for graphic papers. Consumption per capita in Romania is relatively low compared to the European average.

According to some studies potential of wood industry by products equals 19.1 PJ. (Kallivroussis, 2000) but other studies estimated potential of wood industry by-products as 26 PJ (including solid industrial by-products 23 PJ and black liquors 3 PJ). Of these amount already used are 9.0 PJ of solid industrial by products and 2.5 PJ of black liquors (VTT, 2000). Latest assessment showed amount of solid industrial residues in Romania at the range of 549 ktoe/a (22.3 PJ) and industrial black liquors 72 ktoe/a (2.9 PJ) (BTG, 2004)

Bulgaria

Forest industries in Bulgaria use domestic wood to meet local demand for sawn-wood, panels, pulp and paper. The average amount of the waste material produced by the timber industry is estimated at 10% for the ‘standing’ coniferous timber and 12% for the ‘standing’ deciduous one. The above percentages do not include the amount of stumps, roots, foliage and other losses that accompany the felling of trees. The total amount of not-utilised wastes in timber production is about 525 thousands m^3 per year. If production of low grade wood from sucker forests is increased along with improved utilization of the wastes from the production of construction (high-grade) timber, the amount of wood material available for the production of chopped wood particles for the purposes of energy production has been estimated to stand at 2525 thousand m^3 per year.

This potential does not include the widely used in the country firewood amounting to about 860 thousand of dense m^3 per year, neither the unused waste from the woodworking and pulp industries (BioNorm, 2004). According to biomass potential assessment amount of wood industry by products is 51ktoe (2.07PJ) including solid industrial by products-30 ktoe/a (1.22 PJ/a) and industrial black liquors 21 ktoe (0.85 PJ/a) (BTG, 2004).

8.4 OTHERS

The main types of agro-industries in Greece are: rice industries, cotton-ginning factories, corn industries, fruit industries, wine factories, seed oil industries, olive industries, olive oil and olive kernel factories. It was estimated that 0.594 Mtons of MD of the above agro-industrial residues are produced in Greece with a total energy potential of 10 PJ/year.

Table 41: Characteristics of industry residues studied for Greece

Industry	Residue	Residue /Product ratio	Moisture (%)	Production (dry tons/year)
Rice mills	Rice husk	0.16	10	30.311
Cotton ginning factories	Cotton ginning residues	0.1	13	132.079
Peach canneries	Peach kernel	0.04	20	6.400
Olive kernel factories	Olive kernel wood	0.21	30	423.110
Peeling plant	Walnut shells	1.5	8	119
Peeling plant	Almond shells	0.95	5	1.328
Peeling plant	Hazelnut shells	1.07	5	395
Total				593.742

According to the Renewable Energy Sources Statistics for 2000 in Greece (CRES. 2002). Several cotton ginning factories use their residues to produce heat, required for cotton drying and space heating of their facilities. Most of the olive kernel wood produced is used for greenhouse heating and space heating. The total heat energy produced being 8.3 PJ/year. Fruit kernels and the nutshells are also used for greenhouse and residential heating (0.01 PJ/year). Rice husk is used as a fuel for process heat in the rice mills (0.09 PJ) and for power production in one factory (0.44 MW_{el} installed capacity).

9. REGIONAL STUDY – ALPINE REGION (ESU)

9.1 AGRICULTURE RESIDUES

Permanent pastures are the dominant form of agricultural land both in Austria and Switzerland. Arable land in Austria covers 41% of agricultural land, in Switzerland only 26%. Cereals are not the dominant crops.

Table 42 Cereal production in Alpine region (FAO, 2002; ESU, 2004)

Country	Arable land	Cereal area	Cereals share in arable land	Cereals yields 1998-2002	Cereals straw harvested	Straw for energy
	1000ha			t/ha	Mt/year	Mt/year
Switzerland	413	136.1	0.3	6.1	?	-
Austria	1399	590.0	0.4	4.7	2.1	0.6

Switzerland

The following agricultural products and residues for energy use are taken into consideration in Switzerland (Hersener and Meier, 1999):

- *Rape seed oil, Miscanthus, Hemp, grass, hedges*
- products from landscape care (areas of nature protection, residues of mowing of reeds etc.)
- straw and other harvest residues.

Actually about 3,700 t DM (dry matter) of agricultural products (0.1 PJ) and 7,800 t DM (0.1 PJ) agricultural residues are used for energy production in Switzerland. This corresponds to 0.2 PJ primary energy. (Hersener and Meier, 1999) They evaluate that the total potential of agricultural products is up to 305000 t DM (4.6 PJ), of products of landscape care to 25,000 t DM (0.4 PJ) and agricultural residues to 38000 t DM (0.6 PJ). This would raise available primary energy to 5.6 PJ. (Hersener and Meier, 1999) They evaluate the ecological potential of agricultural products and residues in the future at 5.6 PJ. Straw is used in Switzerland for litter and must even be imported (Hersener, 2004). There is no straw surplus in Switzerland. Straw in dung from litter can be used as energy, however only in power plants bigger than at least 500 kWth. Due to the structure of agriculture and restricted possible sites, the share of straw which can be used as energy in dung must be estimated to be 1% (Hersener, 2004).

Austria

The potentials for agricultural products and residues in Austria is recognized as following (Handler et al., 2003):

- In Austria it is allowed to grow energy crops and renewable primary products on set-aside land. In 2001 only 12% of set-aside land was used for this purpose.
- Average yield of straw is 2.1 Mtons straw. About 1 Moons is used as bedding. The literature estimates the potential of energy and material used to be 600,000t per year.
- The Neusiedler lake has a reed surface of 6,000 ha. The usable potential would be about 30,000 t.
- In the next few years, about 400,000 ha grassland won't be needed any more for food production. The use of hay from these surfaces is being studied in research projects.

9.2 FORESTRY RESIDUES

Switzerland

Actually, about 10% of the Swiss forests are used for energy production. The total energy production of forests, orchards and vineyards was 17.7 PJ in 1998. With an increase in the degree of utilization of forest area, groves, orchards and vineyards, the potential of biomass in the future would be 44 PJ, thereof the biggest share would be from forest areas (Hersener and Meier, 1999).

Production of bark in the year 1999 was at the level of 0.7 Mm^3 (4.83 PJ) and utilization for energy at 0.4 Mm^3. Thus surplus of bark that could be used equals 0.3 Mm^3 (2.07 PJ). (Hersener, J.-L. & Meier, U. 1999)

Austria

Wood is the most important biomass supply in Austria. Actually, about 3 Mm^3 woods are being used for energy production. Forest area is growing in Austria. Wood use is 19.5 Mm^3, the increment of wood supply is 27.3 Mm^3. (Handler et al., 2003)

9.3 WOOD INDUSTRY BY-PRODUCTS

Switzerland

(Hersener and Meier, 1999) This paper doesn't give any information on this category. However, the recycling rate of paper and waste wood as well as utilization grade is already high, so that there is only little potential of increase for this category. Other studies estimate waste wood and waste from the paper/cardboard industry used for energy production amounted to 21 PJ in 2001. The authors of the aforementioned study estimate the possible increase in the degree of utilization of these residues as low, as recovery grade and utilization grade are already quite high. Therefore the calculated ecological potential for 2040 is 24.2 PJ, only 3.4 PJ more than in 2001.

According to national studies (BfS/BUWAL 2003) wood industry by-products production was at the range of 0.8Mm^3 but they are fully used.

Austria

(Lechner, 1998) This paper indicates the quantity of residues in Austria. Wood-industry total by-products were 773,000 t in 1997; 98.1% of this quantity is used, 1.9% is disposed of as waste. Wood-pallets/package wood (trade materials): total residues were 106,000 t in 1997. 64% of this quantity is used in the company itself, 33% is recycled outside of the company. About 3% are disposed of as waste and could be used for energy production.

The sawmill industry processed 11 Mm^3 timber wood and generated 4.2 solid Mm^3 residues. 38% of bark (0.375 solid Mm^3) is used for energy production in the sawmill itself, the rest outside of the company also for energy use. 98% of the rest of the residues are used in the wood and paper industry; the remaining 2% are used in the sawmill itself.

Production of industry by-products was at the range of 6.45 Mm^3 but there exist no surplus that could be used in energy. (Lechner, 1998). Other estimates (VTT, 2000) have shown similar values of by products potentials of 50 PJ, but there is no available surplus of industry by-products in Austria.

9.4 RESTRICTIONS (POLICIES AND MARKETS)

Switzerland

The Swiss agricultural policy defines the goals of agriculture in Switzerland, which are to maintain a multifunctional agriculture with food production. It can be assumed therefore that grassland will be mostly used for animal production also in the future and that the energy production with biomass will stay marginal.

The forest area is ruled through the “forest law” in Switzerland (Schweizerisches Waldgesetz), which defines the sustainable use of the Swiss forests. The forest area is protected.

Until 2000 the confederation paid aid money for wood furnaces. Now only a few cantons are granting subsidies for wood furnaces. A recommendation from the confederation exists for electricity from biomass, the plant operator must however achieve its implementation through the electrical power supplier.

Wood wastes from wood industry are already used as a raw material in other industries. In the future a competitive situation will occur between use in energy production and in material recycling.

Austria

Renewable fuels are advantaged regarding to taxes in comparison to fossil fuels. This advantage has given a great impulse to the use of biomass for energy in the nineties. Since 2003 electricity from biomass is also supported from the state.

Wood wastes from wood industry are already used as a raw material in other industries. In the future a competitive situation will occur between use in energy production and in material recycling.

10. ENERGY CROPS – OUTLOOK AND R&D RESULTS

10.1 EAST EUROPE CEE-8 (ECBREC)

The Slovak Republic

In Slovakia research tests with the LC energy crops until now were limited, however some research is provided with amaranthus (*Amaranthus cruentus L.*) – annual C4 crop cultivated in South America (Viglasky, 2003). Expected results will be presented in 2004, 2005.

Poland

Ligno-cellulose energy crops i.e. *short-rotation* woody and herbaceous species have gained growing interest since 1990. This resulted from factors i.e.: (i) bottom-up interest in agriculture development and renewable technologies implementation, (ii) strategic renewable energy targets in PL, (iii) limited wood and it's by-products potentials, (iv) environmental benefits of energy crops cultivation.

Willow *Salix viminalis* (woody)*;* Many R&D trials were conducted in Poland on the use of *Salix* for different purposes. Yields in R&D tests reported in review studies were between 05 – 25 t DM per ha*y^{-1}, however research results have not been proved yet in commercial production (Majtkowski, 2001). Research fields with Salix cultivation have been provided in Poland since 1990 including various trials on poor quality lands, medium and also good quality lands. Densities of 10-60 thousand cuttings per ha were tested. Recommendations for fertilisation based on research fields are 20-30 kg P_2O_5/ha, 40-90 kg K_2O/ha and 30-90 kgN/ha depending on crops growth year. There were more than 150 genotypes clones tested including development of 3 new polish genotypes. Yields of 11-18 t DM per ha*y^{-1} were obtained in research fields when density of planting was 40.000 cuttings/ha on medium quality soil (Szczukowski et al., 2004)

Since 1997 there was established ca. 1000 – 1200 ha Salix plantations, mainly small scale: 1–10 ha, larger do not exceed 50 ha (ECBREC, 2003). The majority of Salix plantations are in an early phase and thus they're not operating commercially on a broader scale. Salix seems to be the most promising woody SRC energy crop in Poland in the medium-term perspective.

Sida hermaphrodita (herbaceous) This perennial crop has been tested in Poland based on research cultivation in the USA. Research tests showed yield up to 15 t d.m. per ha*y^{-1}. Cellulose content tested was 53% DM of total mass (Borkowska H., 2002). In comparison with willow Sida was promoted by single R&D trial. It is hardly possible to evaluate the opportunities for wider cultivation of *Sida h.* for energy purposes as none of the wider proven R&D programme has been developed and proved.

Few R&D units investigated cultivation of *Miscanthus* in PL incl. (*Miscanthus giganteus, Miscanthus sacchariflorus, Miscanthus sinensis)*. R&D tests showed great difficulties to take roots. This resulted from the two general planting options (i) in vitro method or (ii) by use of seedlings. The latter is more expensive while the first was assessed as a risky method (Majtkowski J., 2001). Yields obtained in R&D tests based on experiments in western Poland may vary 13 – 20 t DM per ha*y^{-1} (Pude, 2001).

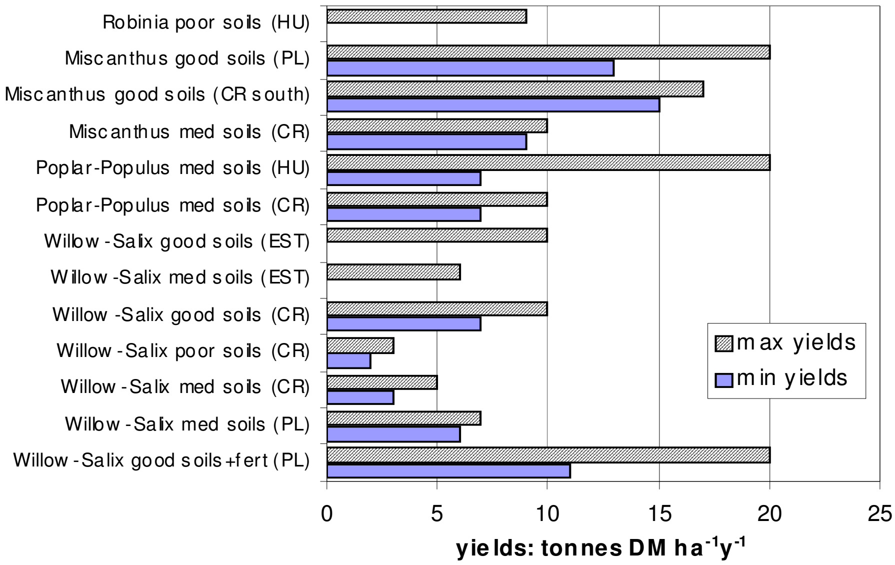


Figure 28: Yields of energy crops research cultivation in CEE countries (ECBREC-review, 2004)

The Czech Republic

Concerning the lingo-cellulose energy crops, cultivation is at an early stage of development. Rough estimates showed ca. 50 ha of willow-Salix plantations cultivated as demonstration and research fields. From 2001, Salix cultivation may receive 1600-2500 EUR subsidies for plantation establishment. During the research of short-rotation woody species willow *(Salix)* and Poplar *(Populus)* were cultivated (Weger and Havlickova, 2002). Some research with SRC woody energy crops started in 1993. Willow *(Salix)* and Poplar *(Populus)* were cultivated based on different clones trials. The average yields obtained were 2-6 tons DM/ha yr based on different soils incl. 2-4 ton DM/ha*yr on poor soils, 3-5 tons DM/ha*yr on medium quality soils cultivated with cereals and 5-6 tons DM/ha*yr on best-quality soils. Research with the best clones of *Salix alba, S. caprea, S. rubens and S. viminalis* (out of 22 clones tested) and more advanced cultivation practices (i.e. well developed weeds control, intensive fertilizing) showed results 7-10 ton DM/ha*yr on medium and good-quality soils. Poplar research cultivation (13 clones tested) resulted with 5-8 ton DM/ha*yr yields (Weger and Havlickova, 2002).

The Czech Research Institute for Crops Production (VURV) also provided research in ligno-cellulose energy crops i.e. reeds and grasses. Various species were tested e.g. *Sorghum, Miscanthus, Cannabis* and others. Research cultivation was provided in different parts of the country including different soils and agriculture conditions. Some of the results obtained in the test are presented in *Table 43*. Research results showed that in the warmer areas of CR higher yields were obtained by Sorghum and Reynoutria (during the 3rd year of cultivation), while in cooler areas higher yields of shoots were obtained by Reynoutria, Secale cereale, Triticosecale (Strasil, 2001).

Table 43: The examples of energy crops yield research cultivation (dm t/ha) (Strasil, 2001).

Energy crops	**Yields of energy crops dm t/ha (dry matter)**			
Location of research field	**Ruzyně**	**Lukavec**	**Troubsko**	**Chomutov**
Cannabis sativa	3,2-15,3	2,6-13,9	7,0	6,2
Secale cereale	8,1-9,5	6,5-11,7	8,8-10,0	6,0-9,3
Sorghum vulgare	5,7-20,0	2,0-9,6	7,8-38,9	3,8-5,1
Althea roseax	13,8-15,3	-	-	15,2-22,4

Baldingera arundinacea (x)	7,1-14,6	-	7,2-8,6	3,3
Reynoutriaxx	31,9	-	-	37,5-73,3
Miscanthus sinensis (xx)	9,3-10,6	2,0	15,7-17,3	-

(x) during the second year after planting, (xx) during the third year after planting

Estonia

Estonia possess quite a large fraction (ca. 30% equalled to 350,000 ha) of poor quality agriculture areas, therefore energy crops potentials is limited. In 1993 research with Salix cultivation has started (Heinsoo and Koppel, 2002). Cultivation resulted with yields up to 10 tons DM/ha*y (44 tons dm/ha during 4 years harvest cycle) when good production practices were set i.e. high-quality soils stands, well managed weeds control and high fertilizing rates. Test on the medium quality soils resulted in yields not exceeding 6 t DM/ha*yr Figure 29. The production density was ca. 20.000 cuttings/ha and the clones used were *Salix viminalis* and *Salix dascylados*.

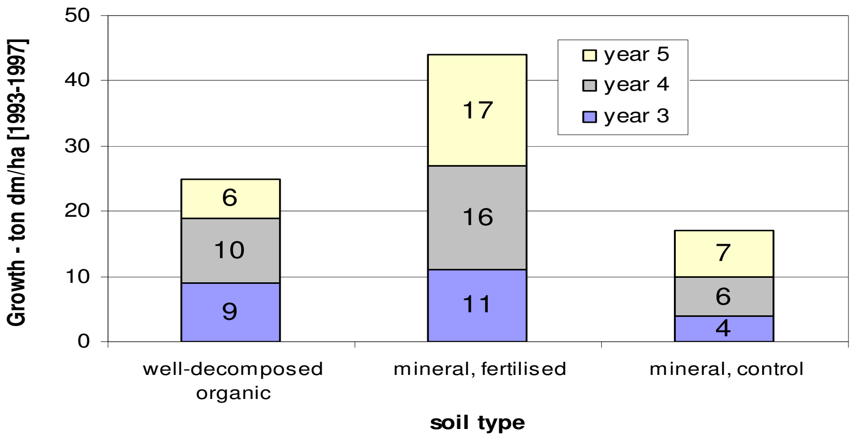


Figure 29: Willow-Salix yields obtained in research cultivation in Estonia (Heinsoo, Koppel, 2002).

Lithuania and Latvia

In Lithuania a few species of ligno-cellulose energy crops were tested in the mid 90'ties, incl. sunflower, hemp, corn and grasses; *Reed Canary Grass - Typhoides arundinacea*, *Reed fescue grass – Festuca arundinacea* and *Poa pratensis*. Hemp obtained the worse yields in research tests not exceeding 3-4 ton DM/ha*yr, while grasses yields varied from 7-13 ton DM/ha*yr. Sunflower yields obtained varied 8-13 ton DM/ha*yr. (Jasinskas, 1998). Ligno-cellulose energy crops production has not been commercial yet, thus subsidy support does not exist as well as forestry wood residues and resources are much more significant in terms of energy potentials.

Table 44: Research results of energy crops cultivation in Lithuania (Jasinskas, 1998)

Energy crop	**Yields of energy crops DM t/ha (dry matter)**		
Nitrogen fertilisation	**Hemp**	**Sunflower**	**Reeds (*Typhoides, Festuca*)**
	3.4	8	6.9
N0 + lupines	3.7	10.6	7.5
N0 + sweetclover	3.6	14.8	13.5
N60	4	10.8	7.5
N90	4.2	12.9	9.6

In Latvia there were not many research programmes in LC energy crops cultivation, thus the knowledge on perspectives and field results are not widely published yet. There's no need to investigate more specific results in Latvia as similar conditions apply to Lithuanian agriculture.

Hungary

There were several energy crops tested in Hungary. The majority of tests were provided with woody LC crops – *Willow (salix), Poplar and black-locust (Robinia)* (Horvath, 2003). The research results showed good, promising results of the woody-species cultivation i.e. Salix yields of 11 tons dm/ha*year (13,000 cuttings/ha) on wet-flood soils, Poplar yields of 7-20 t DM/ha*year (8-11.000 cuttings/ha) on medium-quality soils, and Robinia yields of 9 tons DM/ha*year on poor-quality sandy soils (12,000 cuttings/ha). Also Sweet Sorghum and grasses species were tested, however results of cultivation has not been presented yet (Chrappan and Zanowszky, 2003). There's no commercial cultivation of LC energy crops in Hungary yet, thus demand~~s~~ markets for energy use is still in an early phase of development.

10.2 NORTHERN EUROPE (LUND UNV)

Sweden

Sweden is one of the leading nations in the world regarding knowledge about ligno-cellulose energy crops, especially Salix (*Salix viminalis*), which is a willow crop. Currently there are approximately 16,000 ha of willow cultivations and willow is by far the most common energy crop in Sweden. The average yield is 4-5 tons DM/ha a year. If the plantations are properly fertilized and have no significant weed problems, the yield can be more then 10 tons DM/ha a year (Larsson, 2003).

Several research programmes are developing new varieties of energy crops that are more productive, have a greater resistant against pests and diseases and are better suited for the northern climate since willow can not be used in the northern part of Sweden today. There are also research programmes that focus on applied subjects such as technical improvements to machinery (Larsson, 2003).

One of the other species of energy crops that is being investigated in Sweden is for example *Reed Canary grass* (RCG). Studies indicate that the productivity of RCG is at the same level as high productive willow plantations and that RCG also can be used in the northern half of Sweden. RCG is best suited for upgraded fuels such as pellets and briquettes (Olsson, 1997).

Finland

In the southern part of Finland, willow can produce biomass in the same amount as in Sweden. Willow cannot be grown however in most of the country, whereas, for example, RCG can be grown instead. Other energy crops that have been studied in Finland are grey alder (Alnus incana) and silver birch (Betula pendula). After nine growing seasons the biomass production from grey alder was measured to be 18.5–25 tons/ha while the silver birch only reached a level of 8-13 tons/ha (BASREC, 2000). Though grey alder has a much higher productivity than silver birch, it cannot compete with the biomass production of willow and RCG.

Denmark

In Denmark several different energy crops have been investigated. Willow yields an average of 7.5 tons DM/ha a year in Denmark (Heding, 199). This is higher than the empirical data

from Swedish plantations but lower than the yields that are expected in Sweden with proper fertilization and weed control.
Reed canary grass grows naturally in Denmark and studies indicate a yield of 9 tons DM/ha a year for some genotypes while genotypes from the northern part of Sweden, and in Denmark ~~yields~~ yield half as much (Mortensen and Jorgensen, 1999).
Miscanthus has been evaluated in Denmark since the 1960´s. On research plots the biomass production has reached over 20 tons DM/ha a year, whereas spring yields by farmers have been 7-9 tons DM/ha a year (Jorgensen and Bonderup, 1999).

10.3 WESTERN EUROPE (IE_LEIPZIG)

Woody crops

Willow (Salix sp.)
Willow is grown mainly in the northern parts of the EU including the Netherlands. It is estimated that current average net yields are between 5 and 20 t/ha/year (tonnes of dry matter). Willow production seems to be environmentally friendly. The crop water requirement is high, and often water availability is the factor for the production. Heterogeneity of fields has a strong influence on yield. The long crop rotation, the lack of long-term legislation and the risk of increased pest problems are among the barriers.

Poplar (Populus sp.)
Poplar can be grown in warmer climates than willow. In some countries like Belgium, and Germany both species are grown. Plant density varied between 700 and 1,700 plants/ha. Harvest intervals of 4-6 years are common. In the Netherlands about 32,000 ha (1996) of poplar has been established but not for energy purposes. In France about 350 ha (1996) has been established used for pulp production and a planting density of 2,000 plants/ha was used. Annual yields expected mean 10-15 ton DM./ha. In France annual yields of 6-12 ton DM./ha (dry matter) were estimated under commercial conditions. Compared to willow poplar seems to be more resistant to pests and disease but high establishing costs are known. Poplar does not tolerate high soil contents of heavy metals.

Eucalypt (Eucalyptus sp.)
The large area of eucalypt has been grown in Portugal, Greece and Italy. Almost entirely the species *E. globulus* is used which is very frost sensitive and cannot be grown north of the Iberian peninsula. In France a total of about 500 hectares (1996) of eucalypt was planted for pulp production (density 1,250 plants/ha). There the potential of production under commercial conditions was estimated on about 8-14 ton DM/ha/year (dry matter). The large commercial areas in Portugal provided substantial experience on production, harvest and delivery to the pulp mills. The experiences could be easily transferred to the eucalypt cultivation for energy.

Herbaceous crops

Miscanthus sp.
In Germany there were established over 150 ha (1998), in the Netherlands 20 ha (1998) and France only few hectares (1996). In Belgium small research plots were tested as part of the European Miscanthus Network. During research cultivation in Germany yields in the range

15-25 ton DM/ha, depending on soil conditions. Miscanthus cultivation only 8-11 ton DM/ha on sandy soil at spring harvest was reported. However winter losses of leaves can be about 30% (in the northern parts of EU till 50%). Generally, the crop is considered as environmental sound. Nitrogen leaching from fully established Miscanthus is very low but the crop establishment costs are high.

Sorghum (Sorghum bicolour)
Both sweet and fibre sorghum were tested in some reseach trials. In the West only in France (about 15 ha, 1996) and in Belgium sorghum was produced. Yields of 6-15 ton DM/ha were obtained in northern France and 8-20 t DM/ha in southern part. Planting densities of 150.000-200.000 plants/ha seems optimal which is higher than in Greece. Yields of 5-8 ton DM/ha were obtained in colder areas while 12-15 ton DM/ha were obtained in the warmer regions i.e. in Portugal, where 40.000 plants/ha density was applied, with regular irrigation 30 t/ha. Establishment of Sorghum is easy and cheap by seeds especially in southern Europe under irrigated conditions. Nevertheless the crop can be grown at a total water supply of 400 mm, which is less than needed for the production of maize in France. High yields can only be obtained with irrigation. Sorghum fits well into the crop production. However it need to be evaluated whether the necessary water resources for bio-energy production of sorghum are available.

Hemp (Cannabis sativa)
In recent years in the Netherlands hemp was used for pulp production. For energy utilization approx. 5 ha was grown. An area of 100 ha was grown commercially for fibre use. In the Netherlands yields were found to be 10-17 ton DM/ha, with the highest yields on clay soils (Austria: 6-14 ton DM/ha). Hemp can be easy produced with low demands for pesticides and fertilizer. Yields are relatively high compared to the inputs. As an annual crop hemp fits well into crop rotation where it may serve as a sanitary element against pests. Fungi may cause problems in wet years. There is some concern about the handling of the harvested material, the problem being fibres wrapping around shafts, bearings, drums etc.

10.4 SOUTHERN EUROPE (CRES)

So far cultivation of energy crops has not been established for commercial purposes in Greece due to the existing less favourable technical and economic environment. However, some very promising energy crops have been investigated in several research and development (R&D) programmes. R&D efforts for energy crops in Greece started in the late 80's and focused on important technological barriers affecting the successful implementation. In detail, research programmes were conducted on: (i) agronomic aspects, ii) fuel characteristics, iii) environmental aspects of biomass production, iv) conversion to energy and v) economic and social dimensions of energy crops in Greece.

During the last decade more than sixty (60) experiments have been conducted throughout Greece in order to evaluate the biomass yielding potential of several energy crops. So far, the following annual and perennial crops have been thoroughly studied:

- Annual herbaceous crops: sorghum (*Sorghum bicolor L*), ethiopean mustard (*Brassica carinata L. Braun*), rapeseed (*Brassica napus L.*), kenaf (*Hibiscus cannabinus L.*)
- Perennial herbaceous crops: cardoon (*Cynara cardunculus*), giant reed (*Arundo donax L.*), miscanthus (*Miscanthus x giganteus*), switchgrass (*Panicum virgatum L.*)

- Short-rotation perennial woody crops: eucalyptus (*Eucalyptus globulus Labill.*, *Eucalyptus camaldulensis Dehnh.*), black locust (*Robinia pseudoacacia*)

In general, most of the studied crops exhibited good adaptability to Greek climatic conditions as well as high yields in terms of fresh biomass and dry matter. Productivity varied with site, climate, soil, species and agricultural management but commercial yields of over 20 ton DM ha^{-1} y^{-1} (400 GJ ha^{-1} y^{-1}) appears feasible in most of the tested regions. However, differences have been observed so far depending on crop species, climate and cultural practices. A summary presentation of the obtained results for energy crops is presented below.

Sweet sorghum (hearbaceous) has received considerable attention as an energy crop mainly for bioethanol production from the ferment table sugars contained in its stems. Fresh biomass yields in Greece ranged from 45 to 141 t/ha while dry matter yields ranged from 13 to 45 t/ha, depending on site, variety and cultural techniques. The bioethanol potential in well-irrigated and fertile fields was estimated at 6,750 l/ha. Water use efficiency (WUE) for sweet sorghum has been estimated in central Greece at 181 to 206 kg water per kg dry matter while aerial radiation use efficiency (RUE) at 3.5 gr dry matter per MJ intercepted.

Fiber sorghum (herbaceous) It is a hybrid from grain and broomcorn sorghums and has received attention for energy and paper and pulp production. Experimental data obtained so far from central Greece indicate that it exhibits high biomass yields, similar to that of sweet sorghum. Fresh biomass and dry matter yields recorded in the autumn, reached up to 90 and 27 t/ha, respectively.

Kenaf (herbaceous) A large number of kenaf varieties has been tested indicating good adaptability and high yields. Fresh biomass yields ranged from 33.8 to 88.6 t/ha and dry matter from 7.6 to 23.9 t/ha. It should be mentioned that the late-matured varieties were more productive than the early ones. However although seed production was always feasible for the early varieties, the late ones were occasionally able to produce seed, depending on the prevailing climatic conditions during autumn.

Cardoon (herbaceous) is a perennial crop, traditionally cultivated in some places of the Mediterranean area and well adapted in the semi-arid conditions of southern Europe. In the experimental fields conducted in central Greece, the final plant height reached up to 2.6 m, while biomass yields, depending on plantation density, ranged from 17 to 30 tons DM/ha. The respective values for energy potential ranged from 6.9 to 12.9 toe/ha/year.

Giant reed (herbaceous) is a perennial grass species of southern EU well adapted to Greek conditions In experimental fields established by CRES, dry matter yields reached up to 30 tons/ha from unimproved wild populations and conventional cultural methods with an energy potential of 12.9 toe/ha/year.

Miscanthus (herbaceous) is a perennial rhizomatous grass, originating from South-east Asia. In experimental fields in central Greece, the average height of the plantation reached up to 3 m, while dry biomass yields ranged from 11 to 34 t/ha and the estimated energy potential was 13.8 toe/ha/year.

Switchgrass (herbaceous) is a perennial warm season grass that has the capacity for high yields on relatively poor quality sites. In experiments performed in Greece dry matter yields ranged from 14 to 25 t/ha depending on variety and cultural practice.

Eucalyptus (woody) has been extensively used for paper and pulp as well as energy production worldwide. In the EU there are some 850,000 ha of eucalyptus plantations, consisting of two species (*E. globules* and *E. camaldulensis*), typically managed with an 8-13 year rotation. In Greece, very short rotation cycles (2-3 years) and dense plantations (10,000-40,000 plants/ha) have been studied in various regions. Depending on soil fertility and cultural practices (irrigation, fertilisation and plant density) dry matter yields up to 35 tons/ha/yr have been obtained with a respective energy potential up to 15 toe/ha/yr.

Black locust (woody) is a widely spread species for ornamental, forestation and reclamation purposes as well as for timber and energy production, covering all over the world 3 Mha and being third among broadleaved species in terms of worldwide planted area. In experimental fields in Greece, dry biomass yields ranged from 5.6 to 17.1 tons/ha/year. The averaged value for energy potential was 8 toe/ha/year.

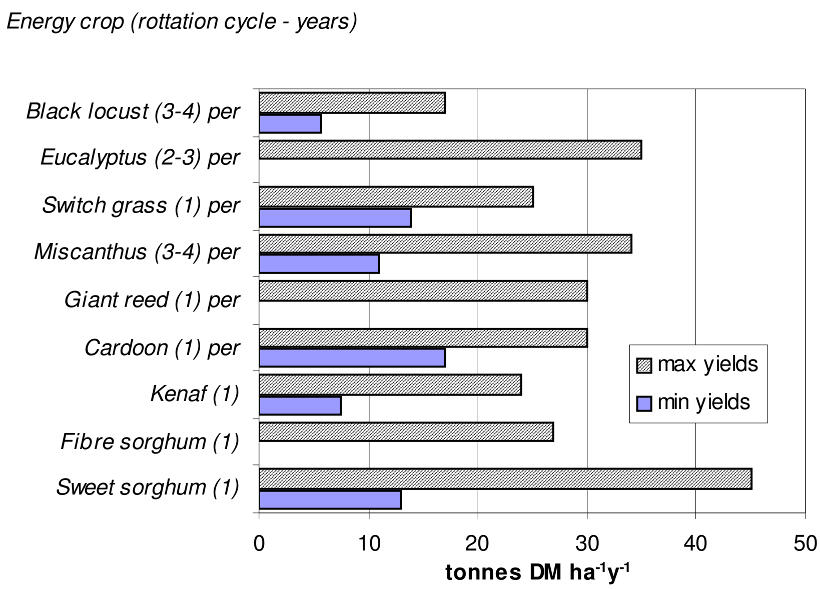


Figure 30: Research results with LC energy crops cultivation in Greece [ton dm $y^{-1}ha^{-1}$] (CRES - own investigation, 2004)

10.5 UK AND IRELAND (NU_DUBLIN)

Energy production from biomass has attracted significance interest in Ireland and the U.K. in recent years. The growth of energy crops to provide an alternative fuel source would help reduce reliance on fossil fuels, reduce greenhouse gas emissions, provide a secure native fuel source and provide some diversification out of the traditional farm enterprises. Presently in Ireland and the U.K., the most likely energy crop plants that can be grown are short rotation coppice, i.e. *Willow* or perennial grasses, such as *Miscanthus*. In addition certain specific crops either with high sugar content, starch or vegetable oil, if the economic situation is favourable, can also be grown for the production of BtL fuels.

Willow SRC – Salix viminalis. Willow *salix* is considered to be the most suitable energy crop in Ireland (Bulfin *et al.,* 1995). Extensive research has been carried out on willow in Ireland. The production of willows varies considerably depending on site conditions and management. Various trials have shown in Northern Ireland and Ireland that annual production from well established plantations will produce yields of 12-14 tons DM per hectare. In Ireland and the U.K. the predominant method of short rotation forestry harvesting is carried out using the cut and chip system with that of large self propelled machines based on forage harvesters (i.e. Claas Jaguar). Cutting and chipping in one single pass can be seen as the most efficient option for harvesting from a harvesting logistics point of view both the forage harvester or the sugar cane harvester can chop willow into small pieces without any difficulty. The use of forage harvesters to harvest short rotation forestry provides an additional use for the machine in a slack period during the winter when all forage has been harvested and improves utilisation of existing machinery, which is critical to reduce the cost of the biomass fuel.

Poplar SRC – Populus ssp. A study of the potential of poplar growing as an alternative to other agricultural systems by Teagasc proved that it was as viable as willow. It was recognised that fertilisation would be required on soils of poor nutrient status. Research concentrated on *Populus* clones, which was mainly on arable agricultural land produced yields for poplar of up to 13 oven-dry tons per hectare per annum on experimental plots, on a rotation of 5 years. The midlands and south-east are most suitable for growing short-rotation forestry, though sites can be found in all parts of the country. In Ireland Teagasc concluded that approximately 40.7% of the total land area, which corresponds to 55.8% of the agricultural area of Ireland, is suitable for growing poplars.

Miscanthus; Current R&D suggests the *Miscanthus* crops appears to be a very promising ligno-cellulose energy crop in Ireland and the U.K. *Miscanthus* productivity trials have been conducted for more than ten years in Ireland. The high yield, low dry matter and ease of establishment are useful advantages. Fields trials throughout Europe have confirmed the potential for the high biomass production from *Miscanthus*. Productivity models from field trials have been scaled up to provide yield estimates at regional, national and continental areas. Model predictions suggest that *Miscanthus* yield in Ireland ranges from 16 t ha^{-1} in the north east of the country to a maximum of 26 t ha^{-1} in the south west (Clifton-Brown *et al*., 2000). In the UK *Miscanthus* peak yields reached 18.6 t ha^{-1} yr^{-1}. Rainfall in Ireland is not limiting to yield but the length of the frost free period will determine the length of the growing season and so will account for some of the inter-annular variation in yield. So far in most cases no specific machinery has been designed for the harvesting of *Miscanthus* but the existing machinery for other crops has been used. There are usually two methods of harvesting. Multi-phase using several machines, mowing followed by swathing, pick-up and baling or single phase using both self-propelled and trailed exact choppers. For direct harvesting, row-independent maize headers will be suitable. In general, self-propelled machines have the highest extraction capacities.

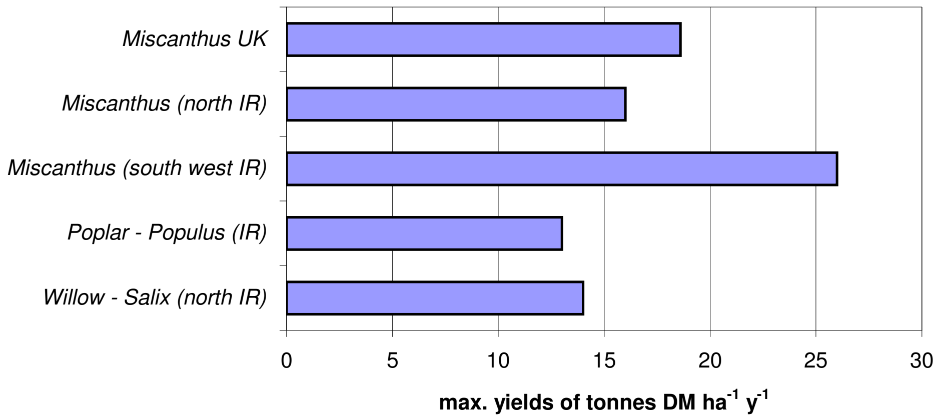


Figure 31: Research results of LC energy crops cultivation in Ireland and UK

10.6 ENERGY CROPS REQUIREMENTS AND MULTIFUNCTIONAL USE

Below we reviewed and discussed basic characteristics of lingo-cellulose energy crops agriculture requirements or some environmental restrictions based on literature. *Table 45* contains the summary of soils and climate requirements of the most promising e-crops as well as characteristics of agricultural operations and needs. From the review it appears that better results were obtained with woody crops *(Willow, Poplar, Robinia)* in Northern Europe and CEE countries. Woody SRF crops usually are growing better on heavy soils, rich in ground water, tolerates 6,0 – 7,0 pH and requires very good soil preparation, several rounds of weed control (preliminary chemical and mechanical) and fertilizing during the first 2-3 year of the plantation. The rotation cycle has been 3-5 years most commonly. The more promising energy crops in southern Europe are the herbaceous species incl. *Miscanthus, Switchgrass, Giant Reed, Sorghum* but also woody: *Eucalyptus, Black locust* research tests showed good results. Usually herbaceous energy crops require~~s~~ soils with good water drainage (light or loamy), tolerates lower pH 5-7 and are sensitive to lower temperatures (frost can damage young shoots).

Table 45: Review of agriculture requirements and environmental conditions of LC-energy crops cultivation in EU (literature review: 1. RENEW WP5.1 works, 2. Bassam, 1998 3. Sahramaa, 2004)

p-perennial; a – annual; (2-3) rotation cycle

	Energy crop	**p/a (2-3)***	**Requirements /soils, climate/**	**Cultivation needs**	**Yield [t DM $ha^{-1}y^{-1}$]**
NORTH	(woody) Salix	p (3-4)	pH: 6,0-7,5, opt.6, 5 Soils: dry locations avoided, light soils as well as loamy soils Temperature: 15-26°C, some species frost tolerant but not below -30°C	High water level, good weed control during 1'st, 2'nd year, med-quality soils, can tolerate salinity	5-15
	(woody) Poplar	p	pH 6.0-8.0, opt.6.5 Soils: sandy, loamy – clay, organic matter and good supply of water Temperature: opt. 15-25°C, cannot survive below -30°C	Med-quality soils, weed control during first few years, fertilizer in planting year gives more benefits to weeds	13

	(herb) Miscanthus	p (3-4)	pH: 5,5-7,5 Soils: deeper (with deep humus), exclude very acid or very chalky, many types of arable land, darker colour and lighter texture could be better for faster growth Temperature: planted rhizomes when 10°C or more	Fertility (magnesium on sandy soils), herbicides C_4 photosynthetic pathway (more efficient in high temperature) young plants can be destructed by frost, weed control	16-26
	(herb) Reed Canary Grass	p	pH:7,3-8,8 Soils: very tolerant to wet, but waterlogged is not suitable because of the deficiency of oxygen Temperature: 6-15°C (verbalization)	Wet fields rich in oxygen, not tolerate drought or salt,	6,8 – 15,7
WEST + CEE-8	(woody) Salix	p (3-4)	pH: 6,0-7,5, opt.6,5 Soils: dry locations avoided, light soils as well as loamy soils Temperature: 15-26°C, some species frost tolerant but not below -30°C	High water level, good weed control during 1’st, 2’nd year, med-quality soils, can tolerate salinity	5-20
	(woody) Poplar	p	pH 6.0-8.0, opt.6.5 Soils: sandy, loamy – clay, organic matter and good supply of water Temperature: opt. 15-25ºC, cannot survive below -30ºC	Med-quality soils, high-water level, careful weed control needed, fertilization gives yielding benefits	13
	(herb) Miscanthus	p (3-4)	pH: 5,5-7,5 Soils: deeper (with deep humus), exclude very acid or very chalky, many types of arable land, darker colour and lighter texture could be better for faster growth Temperature: planted rhizomes >10ºC	Fertility (magnesium on sandy soils), herbicides C_4 photosynthetic pathway (more efficient in high temperature) young plants can be destructed by frost, weed control	16-26
	Eucalyptus (woody)	p (2-3)	pH: low Soils: deep, sandy-clay soils, clay-loams and clay soils (when well drained) Temperature: min.-7ºC, sensitive to lower	Irrigation, fertilization and good plant density, limiting factors are: insufficient depth, poor drainage and salinity.	8-14
	Sorghum (herb)	a	pH: 5,5-8,5 Soils: warm and moist soil, good ability to absorb water Temperature: min.7-10°C for germination, 15°C for growth	Pneumatic sowing machines, weeds control, drought resistant but it needs to be irrigated	6-20
	Hemp	a	pH: opt. 7 Soils: deep, humus rich, calcareous soils Temperature: moderate climate, 13-22°C	Well prepared, supplied with water, not excessively wet	6-17
SOUTH	(woody) Black locust	p (3-4)	pH: 3-7, opt.6 Soils: prefers soils that are rich, deep, moist, well-drained, in full sun to partial sun, shade intolerant Temperature: -25 – 38ºC, opt.15°C	In most cases nitrogen fertilization is not recommended, P and K should be added	5.6 to 17
	(woody) Eucalypthus	p (2-3)	pH: low Soils: deep, sandy-clay soils, clay-loams and clay soils (when well drained) Temperature: min.-7°C, sensitive to lower	Irrigation, fertilization and good plant density, limiting factors are: insufficient depth, poor drainage and salinity.	35
	(herb) Switch grass	p	pH: tolerate acid conditions (neutrality is better), Soils: all soil types are good, Temperature: opt. 10-30°C	Fertility, reduce weeds (with herbicides) C_4 photosynthetic pathway (more efficient in high temperature)	14-25

(herb) Miscanthus	p (3-4)	pH: 5,5-7,5 Soils: with deep humus, exclude very acid or very chalky, many types of arable land, darker colour and lighter texture could be better for faster growth Temperature: planted rhizomes >10ºC	Fertility (magnesium on sandy soils), herbicides C_4 photosynthetic pathway (more efficient in high temperature) young plants can be destructed by frost, weed control	11-34
(herb) Giant reed	a	pH: 4-8, opt.7 Soils: along river banks and creeks, generally moist soil (it is also found in dry and infertile soils)	No special soil preparation requirements	to 30
(herb) Cardoon	p	Soils: not very dry or heavy, light, deep and limy Temperature: -5ºC (when seedlings have four leaves)	Mechanical weed control is preferable (herbicides when mechanical to expensive), preparation like for cereals, fertilizers,	17-30
(herb) Kenaf	a	pH: 6-7 Soils: light to middle weight quickly warming soils, sandy soils Temperature: cold sensitive, temp. from 15°, opt. 15-27ºC	Seeds should be disinfected against anthracnose and fungal disease	7.6-23.9
(herb) Fibre sorghum	a	pH: between 5.0 and more than 8.0, Soils: tolerates salts and alkalis Temperature: opt. 27-30°C	Water-logged soils and acid soils should be avoided	App. 27
(herb) Sweet sorghum	a	pH:5,5-8,5 Soils: warm and moist soil, good ability to absorb water Temperature: min.7-10°C for germination, 15°C for growth	Pneumatic sowing machines, weeds control, drought resistant but it needs to be irrigated	13-45

E-crops have also additional positive aspects of its cultivation i.e. multifunctional environmental purposes of crops growing (fertilizing with sludge, irrigation with waste-water, reclamation of lands or landscape management) as well as use for other goods production. Table 46 presents a summary of multifunctional L-C crops use.

Table 46: Review of multifunctional use and cultivation of LC-energy crops

	Energy crops	Possible use in other industries
Woody (tree species)	Willow (woody) (Swedish experiences)	Salix yields and profits were improved by using sewage sludge as fertiliser. Sludge application is not permitted on food crops and disposal in landfill makes utilization costly. A number of municipalities in Sweden have agreements with Agrobränsle AB, to spread sewage sludge on Salix fields. In 2002 half (50%) of the harvested plantations in Sweden were fertilised by sludge (1.000 ha).
	Black locust (woody)	Pulp and paper production, leaves and young stems for fodder, leaves and young stems for solid, liquid or gaseous fuels, and extraction of specialty chemicals such as natural wood preservatives, honey
	Poplar (woody)	Wide possible use in wood industries
	Eucalypthus (woody)	Therapeutic oil plant
Herbaceous	Cardoon (herb)	Pulp and paper, food
	Fibre sorghum (herb)	Pulp and paper
	Giant reed (herb)	Erosion and landscape control, building and insulation materials, animal bedding
	Hemp (herb)	Pulp and paper
	Kenaf (herb)	Pulp and paper, boards production, composites, building and insulation materials
	Miscanthus (herb)	Pulp and paper, composites, building and insulation materials, cattle litter
	RC Grasss (herb)	Pulp and paper, building and insulation materials, animal bedding
	Sweet sorghum (herb)	Sweetener, sugar, pulp and paper
	Switch grass (herb)	-

10.7 ENERGY CROPS RECOMMENDATIONS FOR RENEW

Based on the regional review of research results with ligno-cellulose energy crops cultivation WP5.1 team recommend the following list of energy crops for further RENEW considerations and works. Energy crops glossary and photos is presented in Appendix.

Recommendations for European regions			CEE - 8	West	South	UK + IR	North
WOODY	Willow (Salix ssp.)	p	√	√		√	√
	Poplar (Populus ssp.)	p	√	√		√	+/-
	Black locust (Robinia pseu-doacacia L.)	p	+/-		√		
	Eucalyptus (Eucalyptus ssp.)	p		+/-	√		
	Grey alder (Alnus incana)	p					+/-
	Birch (Betula pendula)	p					+/-
HERBACEOUS	*Grasses*						
	Reed canary grass (Phalaris arundinacea L.)	p C_3	+/-				√
	Switch grass (Panicum virgatum L.)	p C_4			√		
	Kenaf (Hibiscus cannabinus)	a			√		
	Hemp (Cannabis sativa)	a C_3		+/-			
	Cardoon (Cynara cardunculus)	p C_3			√		
	Sorghum fiber (Sorghum bicolor)	a C_4			√		
	Reeds						
	Miscanthus (Miscanthus ssp.)	p	+/-	√	√	√	+/-
	Giant reed (Arundo donax L.)	p			√		

a – annual crops, p – perennial crops, √ good results and recommendations, +/- means that RTD results were not as promising enough to give good recommendations in respective regions, but crops cultivation is possible and under good climate and agriculture circumstances high yields are expected.

11. BIOMASS POTENTIALS IN EU-25 - RESULTS AND DISCUSSION

11.1 AGRICULTURAL RESIDUES

The agricultural residues potential is primarily based on cereals straw due to the fact that cereals are the dominant crops. Apart from cereals straw, maize residues and permanent crops residues are regarded as a raw biomass material available for energy use, however their potential is of less significance.

The total agricultural residues potential available for energy in Europe amounts to 906.13 PJ. The largest part of it is cereal straw 771.16 PJ – see Table 47. The geographically largest countries, such as France, Germany, the UK and Poland have the largest absolute biomass potentials. In each of the three countries the agriculture residues potential for energy was estimated at over 100 PJ/year.

Table 47: Summary of agriculture residues potential available for energy use

Country	Straw available for energy use (% of straw harvested)	Cereals straw		Maize residues*		Permanent crops residue	
		M tons	PJ	M tons	PJ	M tons (DM dry matter)	PJ
Austria	23	0.60	8.64	0.27	1.90	-	-
Belgium - Luxembourg	20	0.34	4.92	0.07	0.50	-	-
Denmark	52	2.39	34.39	-	-	-	-
Finland	66	0.65	9.30	-	-	-	-
France	20	7.84	112.85	2.40	16.80	-	-
Germany	20	8.50	122.44	0.53	3.70	-	-
Greece	20	0.76	10.97	0.30	2.10	0.55	10.0
Ireland	22	0.53	7.63	-	-		-
Italy	20	3.71	53.44	1.52	10.60	1.57	28.55
Netherlands	20	0.23	3.30	0.02	0.10		-
Portugal	20	0.29	4.20	0.14	1.00	0.60	11.04
Spain	20	4.43	63.83	0.65	4.50	-	13.88
Sweden	66	0.94	13.49	-	-	-	-
UKingdom	53	7.7	110.88	-	-	-	-
Switzerland	0	-	-	-	-	-	-
Czech Rep.	-	1.07	15.41	0.05	0.40	-	-
Estonia	25	0.15	2.16	-	-	-	-
Hungary	-	1.98	28.51	0.98	6.8	-	10.20
Latvia	20	0.57	8.21	-	-	-	-
Lithuania	12	0.40	5.76	-	-	-	-
Poland	30	7.50	108.00	0.14	1.00	-	-
Slovakia	-	0.54	7.70	0.10	0.70	-	-
Slovenia	0	-	-	0.05	0.30	-	-
Bulgaria	-	0.94 a	13.52	0.19	1.30	-	-
Romania	-	1.5 a	21.60	1.37	9.60	-	-
Total		**53.55**	**771.16**	**8.76**	**61.30**	**-**	**73.67**

*data from a report: Technical Potentials for Liquid Bio-fuels and Bio-Hydrogen (IE, 2004)
NCV straw 14,4 MJ/kg, NCV maize residues 7 MJ/kg, NCV permanent crops res. 18 MJ/kg
a - data for straw were calculated according to the BASE methodology as any national estimates were not available for Bulgaria and Romania

The agriculture residues available for energy use given in Table 47 include total amounts available for energy purposes, whether it is already used for heat and electricity or not. Straw available for energy use was calculated as a percentage of harvested straw – straw that may be collected from the field (a certain share of straw always remains as gleaning or crumbling losses on the field due to technological limitations).

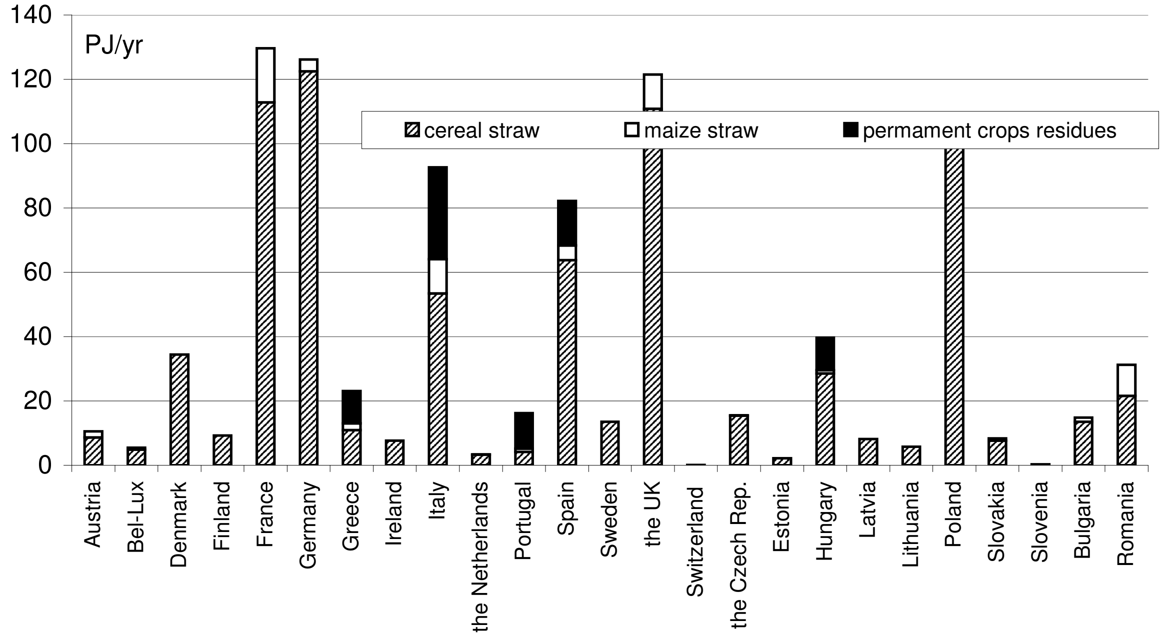


Figure 32: The surplus available for energy uses the Agricultural residues potential in Europe based on fact-finding data

The straw available for energy purposes has to compete with straw requirements for agriculture. Cereals straw has been used traditionally for animal bedding and fodder as well as for crop protection and for mushroom compost. Part of total straw amount is ploughed back into the soil for the organic matter restoration and nutrient re-circulation. The surplus that could be used for energy purposes amounts in most countries at 20% of straw harvested. In Northern countries as well as in the UK it is much higher, while is Switzerland and Slovenia no straw is available for energy. There is a regional specification:

- In Switzerland and Slovenia there is no straw available for energy as the agricultural area is relatively very small and all straw is utilized for agricultural needs. Straw must be even imported for litter.
- In countries of central and eastern Europe small farms and an extensive type of farming is still very common, thus majority of straw is used as an animal bedding in deep litter systems of animals raising. Then, in form of farmyard manure straw comes back to the field. Straw available for energy amounts 10-30% of straw harvested in the CEE countries.
- In Sweden and Finland only 1/3 of straw harvested is used for animal husbandry as the livestock is very small in these countries. In Denmark cereals cover 70% of arable land, which is the highest in Europe. Very high yields are obtained due to very intensive farming. Due to these facts straw surplus available for energy in Denmark is high (52%), even though the livestock is large.
- In western countries straw usage for animals is less significant due to the fact that litter-free systems of animal rising are dominant, however straw is still commonly

used for horse fodder and litter, etc. It is also used for fruit and vegetable protection and for mushroom compost preparation. Some part of the harvested straw shall be left in the field in order to maintain the soil fertility. Only 20% was estimated as available for energy use.

- In the UK over 50% of harvested straw is left in the field as unwanted by-product and this is considered to be available for energy purposes. In the UK and Ireland there is not much value put on the nutrient value of straw in traditional tillage operations.
- In the Southern Europe cereal straw is used for various purposes such as animal feeding and animal bedding. It was estimated that only 20% is available for bio-energy applications.

The share of straw available for energy includes the current use for heat or electricity generation. In most countries it is a little fraction (less than 1% of total straw production), but in Denmark in 1996 straw consumption for energy amounted 900,000 tonnes, which was 15% of total straw amount (Centre for Biomass Technology, 1998).

The straw quantity resulting from cereal production is influenced by the average crop yields and the mass straw/grain ratio. The mass ratio fluctuates between approximately 0.8 for winter wheat and about 1.4 for rye. It also differs among European regions. However, the straw yield are mainly determined by the grain yields, which differ greatly among European countries – see Table 48.

Table 48*: Grain yields, straw/grain ratios and straw yields in European regions (FAO, 2002; RENEW fact-finding)*

European regions	**CEE**	**Northern Europe**	**Western Europe**	**The UK and Ireland**	**Southern Europe**	**Alpine**
	Poland	Sweden	Germany	The UK	Greece	Switzerland
Grain yield * ton/ha	3.0	4.6	6.5	6.9	2.3	6.1
Straw/grain ratio for wheat	0.9	0.8	0.8	0.65	1.1	0.8
Straw yield ton/ha	2.7	3.7	5.2	5.5	2.5	4.9

* average yield of cereals 1998-2002

The highest straw yields 5.2-5.5 tons/ha are obtained in western Europe and the UK and Ireland due to high grain yields. The lowest straw yields 2.5-2.7 tons/ha are in the Southern Europe and CEE countries, even though the straw/grain ratio is higher there. Generally, in western and northern Europe cereals have shorter straw than those cultivated in the central and eastern Europe, which is evident in the straw/grain ratio.

These are factors, which strongly influence the straw availability for energy purposes:
Straw availability for energy purposes is strongly influenced by several factors:

- The cereals area and share of cereals in the cropland.
- Farming structure – if the farms are small and cereals fields are spread among other crops, the straw harvesting and transportation costs might be too high; straw is currently transported 50-100 km maximum for district heating plants.
- Livestock - the higher the amount of livestock, the more straw is used in agriculture
- Use of straw for fruit and vegetable gardening as well as mushroom compost
- Growing conditions - dry climate conditions leads to significant lower yields especially in Southern European countries

- Harvesting conditions - wet climate condition leads to problems in harvesting and storage especially in Northern Europe and in Ireland.

Permanent crops residues, such as fruit tree pruning, olive and grapes pruning, have significant energy potential in the southern European countries. Pruning from grapes, olives and fruit trees are a dominant source of biomass for energy in Greece. It has been estimated that the 20% availability of the residues from vine, olives and fruit trees for energy purposes is a good scenario. Currently pruning from olive oil trees as well as from other fruit trees are already a very common source for heat production, especially in rural and remote areas. However, the majority of them remain unused and farmers in order to clean their fields burn them out in the field (Dalianis and Panoutsou, 1998). The assumption that 20% of total residues from vine, olives and fruit tree is available for energy i.e. BtL production (excluding the current utilization for heat production) is considered as a reasonable scenario (Panoutsou, 2004).

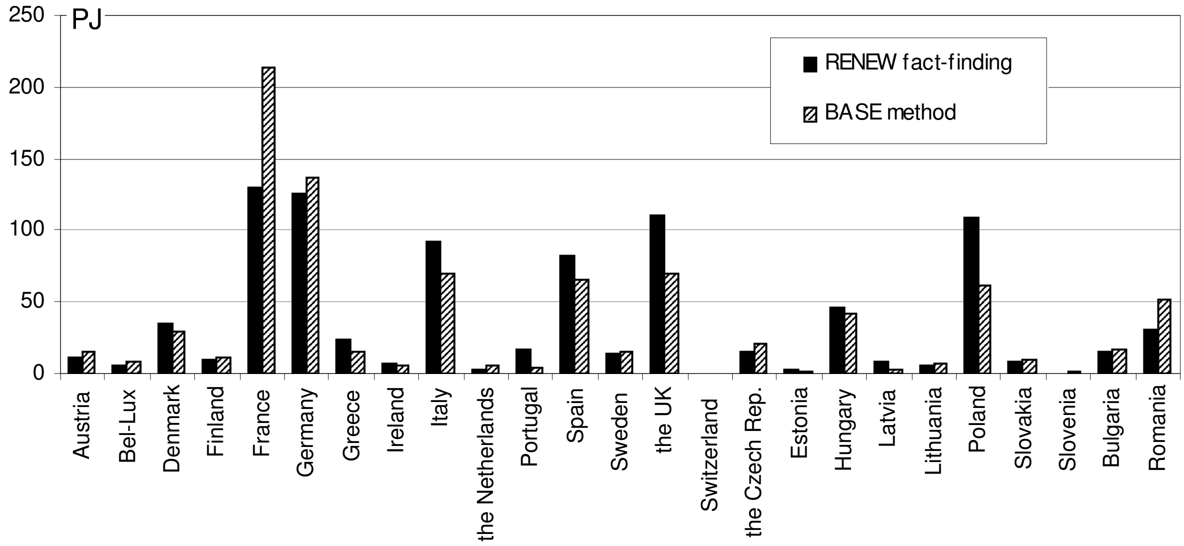


Figure 33: Comparison of agricultural residues potential based on the Base method (Ericsson and Nilsson, 2003) and RENEW fact-finding

The *Figure 33* presents the agriculture residues potentials both according to the assumptions of the *BASE METHOD* and the RENEW fact-finding (see Table 47). The greatest differences in potentials assessment are for France, Portugal, the UK and Poland. For the southern countries, such as Greece, Italy, Spain and Portugal, the potentials were underestimated in the BASE method due to the fact that permanent crops residues were not included in the study. Another reason of the differences in BASE method and RENEW works are the ratios of the residue available for energy purposes. While in the BASE method fixed ratios were used for all countries, the RENEW fact-finding data showed that the residue ratios are different among regions and countries, especially for cereals straw.

Guide for methodology – straw potentials

- Total straw production influenced by grain yields and the gross straw/grain ratio
- Straw/grain ratio differ for cereals species
- Not all straw shall be removed – straw left in the field to maintain the soil fertility – net

straw/grain ratio
- Straw is utilized for agricultural purposes: animal fodder and litter as well as for crop protection and mushroom compost, etc.
- Straw is currently used for energy (heat & electricity) production
- Cropland structure – large farms favour straw production and collection
- Small dispersed fields – not effective straw collection, high transportation costs
- Large livestock = large straw demand for agriculture

11.2 FORESTRY RESIDUES AND WOOD-INDUSTRY BY-PRODUCTS

In general forestry potentials estimates and fact-finding data extraction creates some problems with a precise assessment of both: theoretical and net-surplus biomass volumes for energy use from forests. Logging residues estimates were based on two sources: (i) roundwood production from FAOSTAT database calculated as resides ratios to round-wood produced (as shown in Table 49 column: a) and (ii) national statistics and literature (data in column b). There are significant differences in the calculated values and fact-finding data from literature. Some differences reach even several times greater or lower volumes for residues production estimates.

Table 49:Logging residues, thinning residues and wood industry by products – total production.

Country	Logging residues				Thinning residues		Wood industry by products				
	a1) Mln m^3	**a2**) PJ	**b1**) Mln m^3	**b2**) PJ	Mln m^3	PJ	**c**) Mln m^3	**c**) PJ	**d1**) Mln m^3	**d2**) PJ	**e**) surplus [PJ]
Austria	3.1	21.39					3.9	39	6.45	64.5	0
Bel-Lux	0.72	4.968	1.21 Mt DM*	19.6	0.46Mt DM*	8.6	0.88	8.8	0.55MT DM*	10	
Denmark	0.49	3.38	0.199	1.37	0.5	3.45	0.34	3.4	0.8	8	
Finland	26.64	183.8	8.6	59.34		42.84	14.7	147		182	0.8
France	10.48	72.3	8.13Mt DM*	151.2	9.99Mt DM*	186.0	12.3	123	18.1 Mt DM*	47.3	39.2
Germany	8.58	59.2	9.6MT DM*	178.5	7.00Mt DM*	130	9.72	97.2	16.6 Mt DM*	57	
Greece	0.45	3.1	1.7 Mt DM	1.78			0.48	4.8	-	10.3	
Ireland	0.51	3.52	0.3	2.1	0.6	4.14	0.64	6.4		7.2	4.7
Italy	1.66	11.45		15.03			1.75	17.5		37.77	36
Netherlands	0.24	1.656	0.19 Mt DM*	3.5	0.21 Mt DM*	4	0.29	2.9	0.4 Mt DM*	1.2	
Portugal	1.93	13.31					2.24	22.4		49.4	6.7
Spain	1.88	12.9		58.5			2.21	22.1		65	12
Sweden	28.86	199.2		162.97			15.22	152.2		173	0
UK	1.52	10.5	1.6	11.04	3.8	26.22	0.88	8.8		12	0.6
Switzerland	0.91	6.28	0.7	4.83			1.42	14.2	0.8	8	0
Czech Rep.	2.5	17.25					3.24	32.4		18.84	
Estonia				14.04	0.8	5.52	0.81	8.1	0.59 Mt DM*	11	0.55

Hungary	1.14	7.8	1.21	8.35			1.18	11.8		7.8	2.4
Latvia	1.13	7.8	0.7	4.83	0.6	4.14	1.31	13.1	0.98	9.8	5.5
Lithuania	0.9	6.21	1.76	12.14	1.2	8.28	1.05	10.5		4.7	0
Poland	4.5	31.1	0.9	6.21	2.5	17.25	5.54	55.4	7.4	74	0
Slovakia	1.21	8.3		3.7			1.42	14.2		9.4	5.3
Slovenia	0.39	2.5		2.2			0.46	4.6		6.2	3.3
Bulgaria	0.88	6.1		4.104			0.97	9.7	0.5	5	
Romania	2.47	17.1					2.72	27.2		26	14.5
TOTAL	**103.1**	**711.1**	**15.9**	**725.3**	**10**	**440.4**	**85.67**	**856.7**	**16.9**	**905**	**131.5**

* Note: Data from Institute for Energy and Environment, IE Leipzig Final report from FURORE project: Technical Potentials for Liquid Bio-fuels and Bio-Hydrogen 2004, Leipzig Germany
NCV 6,9 MJ/kg assumed for logging residues and thining residues (forestry residues)
NCV 10 MJ/kg assumed as average wood industry by-products (partly made from fres wood or dry wood)

a) theoretical potentials of logging residues calculated with ratios to stem-wood removals [North EU: 0,4 for coniferous, 0,2 for broad-leaved, rest EU 0,15 for coniferous 0,2 for broad-leaved]. However it is not recommended to harvest because of ecological, technical and economical consideration. Due to this fact we assume that 30% of gross logging residues yield should be left at forest (spread on felling site). See also Figure 11 and Table 2
b) potentials of logging residue based on fact-finding data (literature, studies, national statistics)
c) theoretical potentials of wood industry by-products calculated with ratio to felled-roundwood processing (20% available for energy)
d) fact-finding (literature) data of wood industry by-products production in different countries
e) estimated or literature-based data on wood industry by-products surpluses currently not utilised

For wood industry by products it was assumed that 20% of felled round-wood ends up as industrial by products available for energy use (data in column c). Then we compared theoretical calculations with fact-finding data (data in column d). Values differ in some cases and in some countries information is hardly available. We also reviewed the current demands for by-products and finally calculated if there's any surplus left on the market, that could be net-available volumes for energy use or BtL fuels production (data in column e).

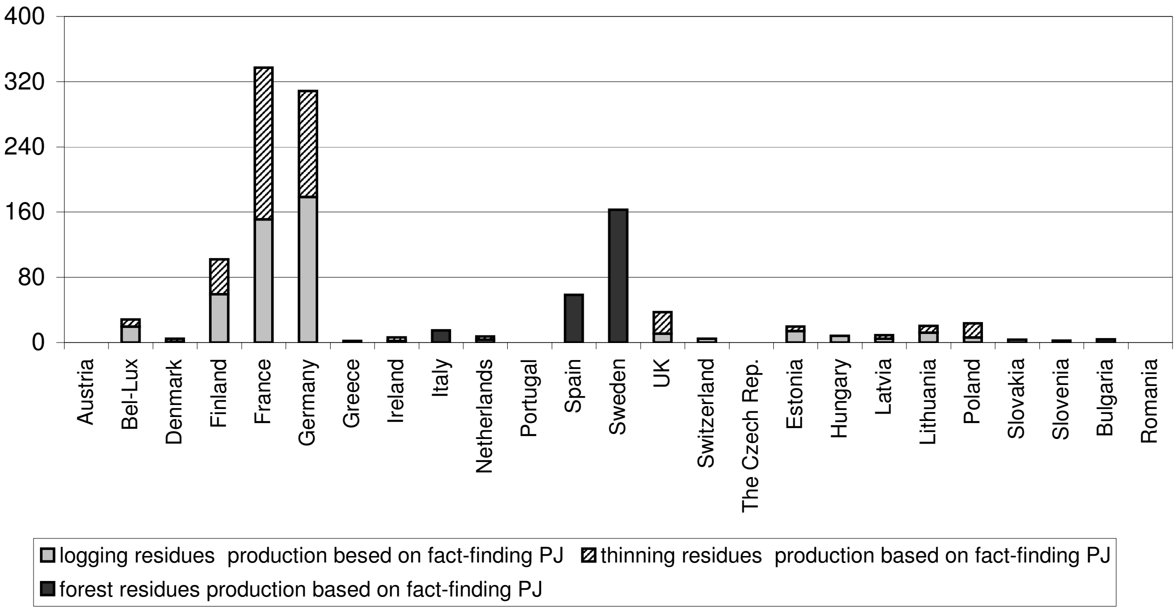


Figure 34: Logging residues and thinning residues potentials in EU-25 [PJ]

As it shown in Table 49 logging residues theoretical potential is estimated for EU-25 countries at 103 Mm^3, which corresponds with 711 PJ. Total volume of potential cannot be extracted due to technical and environmental restrictions. We assumed based on research that 30% of logging residues production should be left in forests. This amount equals 213.3 PJ so the volume is limited to 498 PJ. Literature and national studies review showed similar values of residues potentials of 725 PJ. Forestry potentials in countries sa. Finland, Sweden, Germany, France, Spain and some rich-forestry CEE countries, possess most significant resources of logging residues.

Data collection of thinning residues production created problems. However for some countries it was possible. Literature review showed thinning wood potentials at approximate level of 440 PJ. Based on national and literature studies we can assume that thinning residues production in North Countries: Finland, Latvia equals logging residues potentials and in some countries (Denmark, the UK, Lithuania and Poland) thinning wood volumes is even higher. Thus thinning wood maximum potentials might be regarded as equal volumes to logging residues.

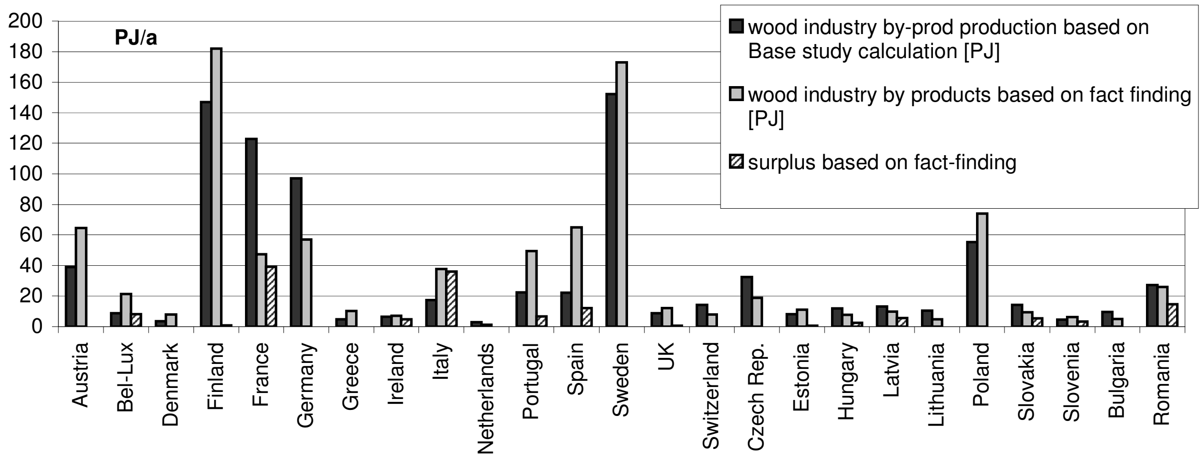


Figure 35: Comparison of wood industry by products production based on BASE METHOD (theoretical potential) and fact finding [PJ]

From the theoretical calculations it occurs that the approximate volume of wood industry by-products is 86 Mm^3 in the EU-25 equalled to 856.7 PJ (NCV 10 MJ/kg). The value based on literature-fact finding data search was estimated at 905 PJ thus it's only 6% higher than theoretically calculated potential. While we searched volumes of surplus residues not demanded currently, it occurs that in some countries almost 100% industrial by-products is utilised. There are large data gaps in estimates or surplus wood industry waste then number of 131.5 PJ presented in Table 49 remains very rough.

Strong demands for wood by-products is in wood industries and for energy production in the domestic sector, district heating or CHP plants in the EU. This makes market surpluses volumes limited. Different sectors strongly compete currently for by-products purchase at the lowest prices (i.e. particle-boards factories, briquettes and pellets factories and district heating plants). North countries are increasing imports of both: (i) raw by-products and processed (ii) pellets or briquettes. In parallel market prices for by-products increase as demands for internal use and export grows in the EU. Thus the available volumes of wood by-products for BtL fuels production are limited and depend on market competition. We expect from the review, that any surpluses of by-products available might be only at the level of 5-10% total production, which roughly do not oversize 100-120 PJ in EU-25.

In the North, i.e. Finland or Sweden there is a far larger production of by-products (up to 180 PJ) but no surpluses left, as there are growing demands for energy use for heat and electricity production in the forestry and district-heating sector. In the 8-CEE countries (especially Estonia, Lithuania, Hungary, Latvia, Slovakia, Slovenia) some volumes of by products exist but not large amounts. In the short term, we expect growing internal demands from the energy sector and increasing export to the North countries, Austria, Germany or others. In southern EU countries (Italy, Portugal, Spain and Romania) there occur some surpluses, that could be used for energy purpose but the biggest possibilities exist in France (surplus at the high of 39,2 PJ).

The differences in theoretical calculations and fact-finding data are for France, Germany. On the other hand in Finland, Sweden, Poland, Spain national studies showed higher values than theoretical estimates. Different proportions between in some countries can be a result of technologies used in wood industry and different efficiencies.

Wood industry in northern and western countries generates less by-products because of more effective technologies. By-products ratio assumed might be diversified for north EU, west EU and accession countries. For example in Poland and South Europe where wood industry technologies are not so effective by-products ratio should be higher. In some cases even 40% of round-wood processed ends up as by-products. The other reason of estimates differences is “fact-finding approach”, under which some values are vague and assumptions hard to prove. Literature studies review showed many differences is assumptions taken for biomass potentials estimates over EU countries.

11.3 ENERGY CROPS POTENTIALS

Energy crops potentials were calculated for the current perspective and the future long-term perspective, to 2020. Based on the current set-aside arable lands and average yields obtained in the research trials of energy crops, we estimated potentials of e-crops cultivation on 100% set-aside lands (equals to 8,2 Mha in EU-25) on 1380 PJ. Respectively countries with a high rate of set-aside lands have the largest potentials in France, Germany, Spain Poland and the UK (between ca. 150 PJ in UK to 260-270 in France and Spain) (equivalent to 1.4 – 1.5 Mha set-aside lands).

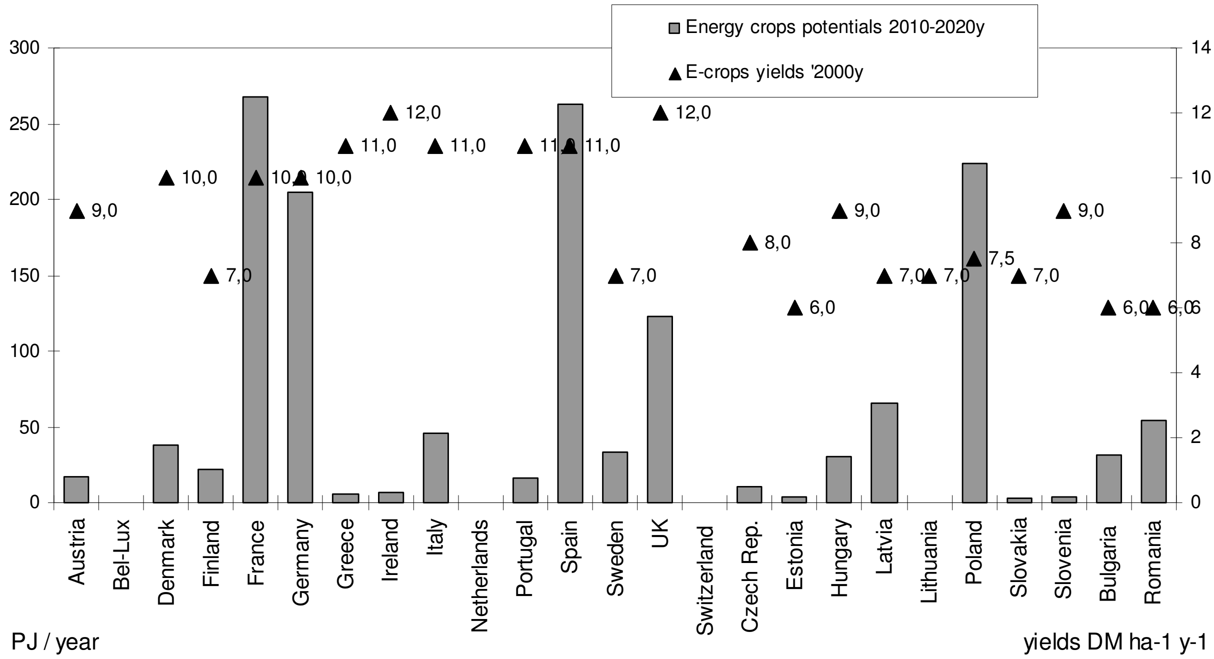


Figure 36: Energy crops potentials based on set-aside land area in 2000y and average yields from research cultivation in EU-25.

The main uncertainties with estimates are related to both: (i) yields assumed (based on the average research trials) and (ii) assumption that energy crops are cultivated on 100% of set-aside land. Basically agriculture set-aside lands could be used for any alternative production and purposes, and the potential is limited when competition is taken into account. Lands differ with soils type, quality, rain-fed water balances, ground water level and soils productivity indicators. Then the assumption of 100% area cultivation is very rough. The land's suitability might be limited due to soil type, organic substances content, pH or water balances for certain crops.

Table 50: Energy crops potentials in EU (long-term >2040 year) – area cultivated (when 0,24 ha/capita demands for food production) and expected average extrapolated yields.

Country	**Set-aside lands in 2000y (FAO, 2002)**	**LC energy crops yields based on R&D**	**Energy crops potential**	**Area set-aside after 2020y (0,24 ha/capita demands for food)**	**LC energy-crops Yields >2040y**	**Energy crops potentials >2040y**
	1000 ha	t DM $y^{-1}ha^{-1}$	PJ	1000 ha	t DM $y^{-1}ha^{-1}$	PJ
Austria	107	9	17,3	1470	9,6	253
Bel-Lux	26		-	0		-
Denmark	213	10	38,3	1304	14,5	341
Finland	177	7	22,3	988	6,3	113
France	1489	10	268,0	13096	14,4	3397
Germany	1137	10	204,7	0	14,7	-
Greece	30	11	5,9	4362	6,8	531
Ireland	29	12	6,3	2193	14,4	569
Italy	231	11	45,7	1519	7,6	209
Netherlands	16		0,0	0	8,1	0
Portugal	80	11	15,8	1790	4,5	143
Spain	1329	11	263,1	16350	7,3	2145
Sweden	264	7	33,3	1041	12,0	224

UK	567	12	122,5	2849	13,9	714
Switzerland	1		-	0		-
Czech Rep.	70	8	10,1	1807	11,3	369
Estonia	33	6	3,6	961	5,8	100
Hungary	186	9	30,1	3100	7,7	428
Latvia	520	7	65,5	1632	6,0	175
Lithuania	0	7	0,0	2416	6,9	300
Poland	1657	7,5	223,7	9149	7,0	1155
Slovakia	25	7	3,2	1145	7,9	163
Slovenia	23	9	3,7	62	8,8	10
Bulgaria	292*	6	31,5	4235	5,6	427
Romania	500*	6	54	9361	5,0	842
TOTAL:	9,0 Mha		**1469 PJ** **1,5 EJ**	80,8 Mha		**12608 PJ** **12,6 EJ**

*source: "Bio-energy's role in the EU energy market. Biomass availability in Europe. Report to the European Commission, 2 April 2004. Data were not available in FAO Agriculture data-base.

Energy crops potentials were also estimated for the long-term perspective. A further decrease of agriculture area for food in the EU-25 was assumed. Energy crops yields were estimated in relation to y'2000 average wheat yields. The yield equation was 2 × wheat yield + 40% increase in CEE-8 (yield increase due to intensification of production in the CEE). Results showed higher future potentials of set-aside lands in France, Spain, Poland and the UK. But nevertheless, in Germany or Italy~~,~~ where there is a higher population density and lower agricultural lands rates/capital, the total potentials were calculated at 11,3 EJ (11340 PJ equivalent to 67 Mha arable lands cultivated). This is 10-times higher than the reference (current set-aside lands) estimates. The EU-25 countries with the largest potential in the long-term are: France, Spain, Poland and the UK, as countries with large agriculture area esp. of medium and low quality and medium population density.

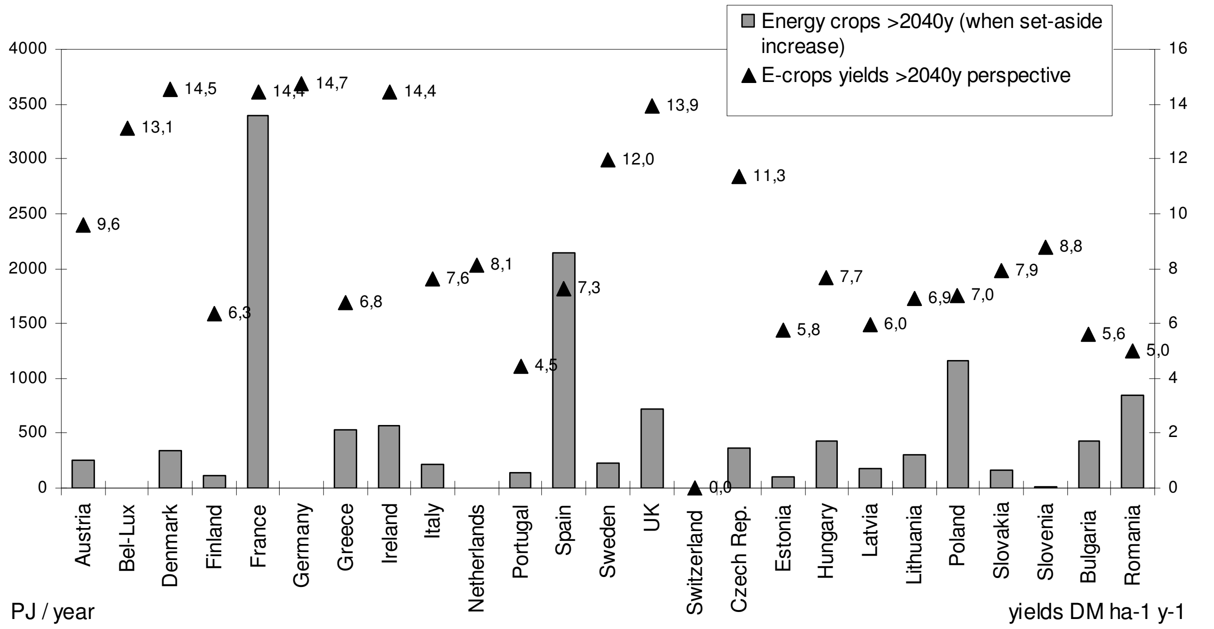


Figure 37: Potential from energy crops in UE 25 in long-term perspective (>2040 year) in PJ, based on extended set-aside lands withdrawn from food-production in future.

11.4 SUMMARY OF EU-25 REGIONAL BIOMASS POTENTIALS

In this chapter we summarised biomass potentials estimates in order to show major differences in EU regions.

Table 51: Summarized biomass potentials in EU-25 regions

Regions	Agriculture residues				Forest res.		Wood industry by-prod	Energy crops			
	Cereals straw	Maize residues	Permanent crops res.	Total	Logging residue	Thinning residue		Area 100% set-aside '2000 y		Area > 2040y (set-aside in future)	
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	Mha	PJ	Mha	PJ
CEE-8	176	3	10	195	81	35	150	2514	340	20272	2700
North: FIN, SE, DK	57	0		57	386	46	303	654	94	3333	678
West: GR, FR, BE, Lux, NL	244	21		265	138	328	232	*2668*	*473*	*13096*	*3397*
UK + IR	119	0		119	14	30	15	*596*	*129*	*5042*	*1283*
South: GR, SP, IT, PR, BG, RO	168	29	63	260	64	-	104	2462	416	37617	4297
Alpine (CH + AT)	9	2		11	28	-	53	108	17	1470	253
Total:	***771***	***61***	***74***	***906***	***711***	**440**	***857***	***9002***	***1469***	***80830***	***12608***

*Notification of data in table:
Agriculture residues values: based on fact-finding data (reflects to 0-30% total straw production)
Forestry residues: (i) logging residue 688 PJ - based on theoretical calculations, (ii) thinning residues – 116 PJ based on fact-finding data (note: data from Sweden, Southern Europe, Alpine countries are missing)
Wood industry by-products: based on theoretical calculation of 20% round wood processing (surplus volumes on the market very limited due to high competition for by-products)

In **Northern Europe** forestry biomass and wood industry-by products are dominant and equals over 80% (432 PJ of forest residues and 303 PJ of wood industry by-products) of total 862 PJ biomass potential. Cereals straw (mainly what and barley) together with projected potential of energy crops on total set-aside agriculture land, both are limited to 20% in the Northern.

For the **North Europe** biomass potentials structure is the following:

forestry residues:	**432 PJ**	**50%**
wood industry by-products:	**303 PJ**	**35%** (high utilisation for energy)
straw:	**57 PJ**	**6,6%**
energy crops:	**94 PJ**	**11%**

Recommendation for further RENEW SP5 assessment as for the Northern Europe is to concentrate on forestry residues and less significant on energy crops.

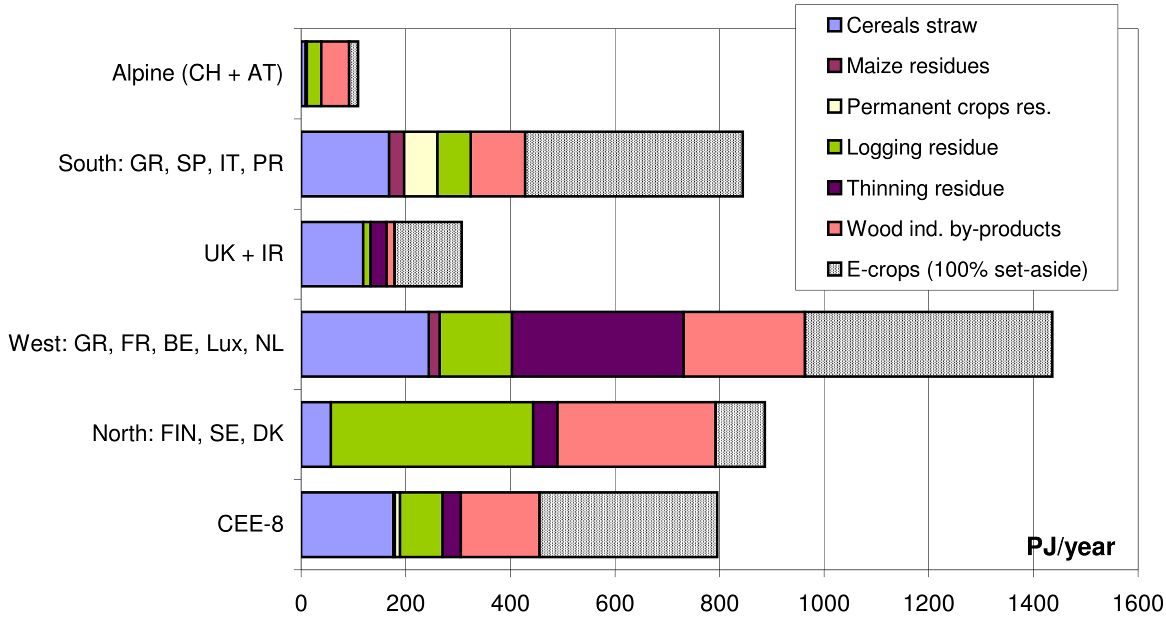


Figure 38: Regional differences in biomass potentials for energy in EU-25 (own estimates, values based in Table 51) Energy crops potentials based on 100% set-aside land in 2000.

In **CEE-8** cereal straw surplus make up 22% of total biomass potentials. Hypothetical cultivation of energy crops on 100% of set-aside land would produce 43% of total biomass potential. Agriculture crops residues and energy crops make up together 65% of total biomass. Forestry residues potential and wood-industry by products roughly equals up to 35%, however both forestry residues and wood industry by-products are meeting strong demands from energy sector and wood industry sector.

For the East Europe biomass potentials structure is the following:

forestry residues:	**116 PJ**	**14 %**	
wood industry by-products:	**150 PJ**	**19 %**	(high utilisation for energy/industry)
straw and maize res.:	**195 PJ**	**24%**	
energy crops:	**340 PJ**	**42 %**	

Recommendation for further RENEW SP5 assessment as for the Eastern Europe is to concentrate on energy crops, agriculture residues and less significant on forestry residues.

In Western Europe the largest part of biomass potential (473 PJ which equals to 44%) is combined with hypothetical energy crops cultivation on 100% of current set-aside land. Agriculture crops residues make up 22% (243 PJ) of total biomass potential. Data on forestry potentials and wood industry by-products need more careful verification, however we expect that their potential is limited to 30-40% of total biomass volume. But both, forestry residues and wood industry by-products are meeting strong competition from the energy sector and policy targets to increase the heat and electricity production from biomass feedstock.

For the West Europe biomass potentials structure is the following:

forestry residues:	**466 PJ**	**32 %**	
wood industry by-products:	**232 PJ**	**16 %**	(high utilisation for energy)
straw and maize res.:	**265 PJ**	**18%**	
energy crops:	**473 PJ**	**44 %**	

Recommendation for further RENEW SP5 assessment as for the Western Europe is to concentrate on energy crops and forestry residues. Less-significant potentials are found as agriculture residues.

In the UK and Ireland hypotetical energy crops cultivation on current 100% set-aside land would produce 129 PJ of primary energy which equals to 53% of total biomass potential. Among agricultural crops residues cereals straw is the dominant biomass resources for energy. Potentials estimated as 119 PJ. Forestry residues and wood industry by-products of 59PJ do not exceed 30% of potentials.

Recommendation for further RENEW SP5 assessment is to concentrate on energy crops and agriculture residues. Less-significant potentials are found as forestry residues.

In **Southern Europe** we expect domination of the potentials from agriculture sector i.e.: 20% straw surpluses (mainly wheat and barley), 3% maize residues and 10% permanent crops residues (woody orchard prunings). Cultivation of energy crops on set-aside land could reach over 50% (416 PJ) of total biomass volume available for energy in the region. The potentials in agriculture equals ca. 260 PJ. Forestry residues and wood industry-by products volumes need more careful verification. However, we expect their potentials limited to maximum 10%-20% of total volume. We expect also high rate of current use for energy and demands in wood industry.

For the Southern Europe biomass potentials structure is the following:

forestry residues:	**64 PJ**	**7%**
wood industry by-products:	**104 PJ**	**12%**
straw and maize res.:	**197 PJ**	**23%**
permanent crops res.:	**63 PJ**	**7%**
energy crops:	**416 PJ**	**51%**

Recommendation for further RENEW SP5 assessment as for the South is to concentrate on energy crops and agriculture residues (incl. permanent crops residues). Less-significant potentials are found in the forestry sector.

In **Alpine region** (Switzerland and Austria) distribution of potentials shows over 70% domination of forestry residues and wood industry by-products (81 PJ) due to high share of forestry in the region and high rate of wood fellings. However, currently forestry residues and wood by-products are demanded for energy production and wood processing industry, thus rather limited market surplus is expected. There is no significant surpluses of agriculture residues.

Recommendation for further RENEW SP5 assessment of Alpine region is to concentrate on forestry residues and wood industry by-products. Less-significant potentials are found as agriculture residues and energy crops.

12. CONCLUSIONS AND RECOMMENDATIONS

12.1 AGRICULTURE RESIDUES POTENTIALS

Agriculture residues potentials available for energy calculated for the EU-25 were: 771 PJ straw, 61 PJ maize residues and 74 PJ permanent crops residues (mainly *woody* orchards residues). Cereals straw is the primary residue in most countries covering over 80% of the total agriculture potentials. In most countries 50-80% of straw harvested is used in agriculture. Net technical potential available for energy (harvested volumes with no market demand) was estimated to be 20-50% of the total straw harvested, however there are countries where all straw is used for agriculture and no surplus is left. Total straw surplus available for energy in Europe equals 54 Mtons. Maize residues that may be used for energy purposes make up 20% of the total residues and amounted almost 9 Mtons in Europe. The same residue ratio was assumed for permanent crops in southern Europe, which was estimated at about 4 million tons.

The straw potential varies in regions. In the North half of the straw harvested is straw available for energy, but cereals area is limited and cold and wet weather conditions discourage straw harvest and storage. The only exception is Denmark with a great straw production, however its current utilization for energy limits the potential available for such uses as BtL fuels production. In the West and central Europe the growing season and harvesting conditions are better than in the cold North and dry South. Large unexploited straw resources are found in large countries, i.e. France, Poland, Germany, the UK and Spain. The highest straw yields per hectare are obtained in the West, the lowest in the South and CEE countries.

Straw utilization for energy is limited to regions of large farms and a high share of cereals in the cropland. Small farming structure faces problems with the high costs of transportation, straw losses and inefficient harvest machinery usage. Also regions with high livestock should be excluded as great amounts of straw are used for animal-farming.

Current straw utilization for heat production is limited to 1-10 MW_{th} district heating plants in East EU (CEE-8) and Germany. Larger energy technologies are found only in Denmark and UK over 50-100 MWt (CHP[2] plants and demonstration Power plants), in regions with intensive cereals production. Utilization of straw in large-scale energy plants may be limited by the availability of straw as a raw material. Currently straw logistics, storage and transportation are feasible from the distances not exceeding 50-100 km. Then raw straw supply for BtL might be regarded as solution for small-scale plants (10-50 MWt input).

<u>Options for large-scale BtL production from straw</u>
Straw processing in plants before BtL fuels synthesis (i.e. into pellets, pyrolysis oil) located in regions with large and highly intensified cereals production, might be considered to be an option for 2'nd step larger-scale BtL production (i.e. >100 MWt). We think that mixing (blending) straw with another raw biomass origin, e.g. herbaceous energy crops, may be another perspective for BtL fuels production from herbaceous biomass in larger scale.

[2] CHP – Combined heat and power plants

12.2 FORESTRY RESIDUES AND WOOD-INDUSTRY BY-PRODUCTS

From the review it appears that approximately theoretical volumes of forestry residues potentials equals to 711 PJ (103 Mm^3) logging residues. Logging residue theoretical potentials states as significant in large-forestry countries esp. Finland and Sweden, France, Spain, Germany and less in Poland. Our review work showed major differences in availability and extraction of forestry residues based on demands in different countries. In the North i.e. Finland and Sweden current market demands (for energy use) are not exceeding 10% of theoretical volume. Additionally to that technical and economic constraints as well as environmental restrictions shows that only 20-35% theoretical volume is technically available for energy supply (Hakkila, 2003). This is due to large forestry resources/capita and long distances for transportation.

In CEE-8 and Southern countries, where population density is higher and forestry resources lower (20-40% country lands) than in North, logging residues are with higher rate used for domestic heating or used in wood industry. We may conclude that rate might be even over 70% of theoretical volumes. Similar distribution might be in West countries where rate of firewood consumption close to forestry areas is high (i.e. in Austria, Germany, France, Italy and Spain.

Regarding thinning residues fact-finding review resulted in estimation 440 PJ potentials in EU-25, however data are rough and vague. It is difficult to estimate thinning wood flows and current demands in EU as proper data are not available or differs among studies and literature. Such an approach needs more time, an advanced data collection and method. In CEE-8 thinning residues are highly demanded by wood industry then surplus market volumes are limited. In West Europe we expect also high rate of consumption by wood industry or for energy. In the North wood from thinning operations are not very much demanded now.

Wood industry by-products potentials were estimated as ranged between 857 PJ theoretical production and 905 PJ from fact-finding literature based data. However we reviewed, that wood processing by-products meets strong demands for energy production (heat and electricity) and wood industry production (particle boards, pulp etc.), therefore market surpluses for BtL transportation fuels are limited.

12.3 ENERGY CROPS POTENTIALS

Energy crops potentials estimates are facing the assumption development for methodologies. We assumed two perspectives: (i) growing on current set-aside lands and (ii) increase of set-aside lands in future due to more intensive food production >2020y, which gives 10-times higher values of absolute potentials. For the short-term perspective (2010y) theoretical potentials were estimated 1,5 EJ and for long-term perspective over 12,6 EJ. Obvious conclusion from the report is that major biomass potentials in EU-25 are met in agriculture lands that could be cultivated with energy crops than from agriculture residues (i.e. straw) and forestry resources.

Main uncertainties relevant for the estimates are: (i) agriculture lands distribution in future and (ii) yields of energy crops (we assumed 6–14,5 tons $DMy^{-1}ha^{-1}$) dependent on region and agriculture experience. Lands distribution for food production is affected by future population preferences, diet and food import/export balances in EU. One can conclude that EU will be with major dominance of own agriculture production self sufficient with food or on the other hand food-importer (fe. from Asia, Africa). Also within last decades food consumption is growing (i.e. meat, dairy products) then this also influence opposite thesis – that food production area might grow in future when EU population will extend food consumption.

Yields of energy crops are dependent on farming practices, unpredictable climate conditions and agriculture capacity increase in East and Southern Europe countries. Eastern and Southern countries are basically worse developed in terms of agriculture production management, intensification and efficiency. Within last decades yields of cereals crops have increased significantly (even 2-3 times) due to more intensive managed farming practices (growth of pesticides and fertilisers use, high-yielding varieties, increase of agriculture mechanisation). However this also may result in negative environmental impact of intensive agriculture production. Therefore expected changes in CAP Policy and Directives (Nitrogen and Phosphorus leakage, pesticides level regulation) would affect very intensive agriculture practices. Then this may result in stabilising crops yields as fertilising and bio-active substances usage will be limited. It's difficult to predict future average yields. That's the reason we estimated potentials with both values: (i) average research results with e-crosp cultivation and (ii) in relation to average most common cereals crop yield - wheat.

Despite doubts of potentials estimates there're existing challenges for research and commercial implementation in EU agriculture system. The major were summarised in some past studies (Venendal et al., 1997). During the production phase those are: breeding for better adapted plant materials production with low input and maximized fuel quality; lowering costs of establishment of perennial crops; efficient weeds control with minimizing pesticides use and mechanical operations; high-water needs and possible implications of ground water recharge. Also multifunctional aspects are relevant during energy crops production i.e. use of sewage sludge or irrigation with wastewater for fertilizing.

Regarding costs production reduction major bootlessness are: (i) high yielding clones with good tolerance for climate amplitudes and pests and rust resistance and (ii) integrated scheme of energy crops subsidizing in early development phase. Illustration could be Swedish case where combining programmes on fundamental biological and environmental R&D, applied support for energy crop cultivation and well provided education and trainings for farmers resulted with reduction of up to 50% plantation costs (from 1200 to 600 ECU/ha) within 5 years period.

Main financial incentives necessary for wider energy crops cultivation are: support for establishment (based on crop characteristics and land properties), subsidies during cultivation life-cycle integrated with CAP support scheme for cereals, definition of relation between subsidies for set-aside operations and energy crops cultivation on set-aside lands. Also regulation of lands allocation to energy crops shall be part of the system and rules for lands cultivation after perennial SRF life-cycle end (i.e. lands properties testing, agriculture operations necessary for the lands allocation for continued food production etc).

13. PROJECTS RESULTS REVIEWED

Within the scope of project work and the report development WP5.1 partners reviewed and used previous research studies in which investigations and estimates of biomass potentials was provided, incl.:

IEE ALTENER 4/1030/C/00-022/2000	Project report *"Energy Potentials of Agriculture Residues in EU"* Manuscript: Center for Renewable Energy Sources - CRES, PIKERMI Greece 2000
DGXII Joule III	Project report: FEEDS: "Fuel wood in Europe for Environment and development Strategies" CLIP, 1998
IEE ALTENER AFB-net phase V	Project report *"Export and import possibilities and fuel prices – Task 2" AFB-net Phase V*, (Final report and Country reports) VTT Energy 2000, Jyvaskyla Finland http://europa.eu.int/comm/energy/res/sectors/finalreportsaltener.htm
IEE ALTENER ENE39/T0039/99	Project report *„Production techniques of logging residue chips in Finland"* VTT Energy Jyvaskyla 1999 http://www.vtt.fi/virtual/afbnet/d1-5.html
FAIR-CT97-3826	Project reports with country surveys in CEE-8; "Development of a bioenergy market development plan for Central Europe. Vol II: *Biomass energy strategies for Central and Eastern Europe"*, 1998 – 2000
FP5 NNE5-2001-00619	Results of the country surveys in CEE-8 countries of the project: *"VIEWLS – Clear Views on Clean Fuels, Data, Potentials, Scenarios, Markets and Trade of Biofuels" 2003 – 2005*
FP5 ENK5–CT–2001-80526	Results of country surveys of the project: "*ERA-Bioenergy strategy. Short-term measures to develop the European research area for bioenergy RTD" 2001-2003*
FP5 NNE5-2001-00158	Country reports prepared under the WPVI Research exchange with NMS of the project: BIONORM – *"Prenormative work on sampling and testing of solid biofuels for the development of assurance systems."* Progress project reports: Country characteristics in New Member States 2002-2004
FP5 DG TREN NNE5/2001/143	Country reports of the project EU-BIOTECH *"Development of portfolios of bio-energy projects in selected countries of Central and Eastern Europe"*
SEP-BIOPOL	Project report *"The comprehensive assessmen tof bioenergy development in Poland"* ECBREC, Warsaw 05.2004 (report restricted to project team) prepared under the framework of Swedish – Polish bilateral research project "Sustainable energy for Poland. The role of bio-energy."
SEP-BIOPOL	Project report *"The use of biomass for energy in Sweden – Critical Factors and Lessons Learned"* Department of Environmental and Energy System Studies, Lund University 08.2002 ISBN 91-88360-53-9 http://www.miljo.lth.se/engelska/eng_index.asp
TEKES – Finland	Intermin project report: *"Delevoping technology for large-scale production of forest chips"* prepared under the framework of Wood Energy Technology Programme 1999-2003 VTT Processes Hakkila Penti, Helsinki 2003, ISSN 1239-1336 ISBN 952-457-101-3 http://akseli.tekes.fi/dman/Document.phx
FP5	Project report: FURORE *"Technical Potentials for Liquid Biofuels and Bio-Hydrogen"*, 2004 Institute for Energy and Environment, Leipzig GER
RENA CT 94-0053	EUREC network on biomass (Bio-electricity)

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Dalianis and Panoutsou, 2003	"Energy Potentials of Agriculture Residues in EU" Manuscript: Centre for Renewable Energy Sources - CRES, PIKERMI Greece
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