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Biomass for Greenhouse Gas Emission Reduction

Sawn Timber and Wood based Products as Building Materials

von

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LIST OF ABBREVIATIONS

BFH	- Federal Research Center for Forestry and Forest Products Hamburg
EU	- European Union
EFTA	- European Free Trade Association
F	- Fellings (volume of cut trees by thinning or clear cutting)
GHG	- green house gas
G	- giga (10^9)
GS	- growing stock given in m³ or Todm o.b. (stock volume in forests distributed in different age classes, changing by felling (harvesting (thinning or clear cutting)) and increment, describes a state)
ha	- hectare
J	- Joule
K	- kilo (10^3)
m³	- cubic metre = m³ u.b.
NAI	- net annual increment given in m³ or Todm o.b. (volume of increment of stock volume distributed in different age classes)
NC	- national currency
N	- nitrogen
m³ o.b.	- cubic metre over bark, unit for growing stocks, increment and fellings. Wood measured including bark
MATTER	- MATerials Technologies for greenhouse gas Emission Reduction
MARKAL	- MARKet Allocation
M	- million (10^6)
m³ u.b.	- cubic metre under bark. Unit for removals = m³, wood measured without bark
odm	- oven dry matter (atro)
OWL	- other wooded land
O&M costs	- operation and maintenance cost

P	- peta (10^{15})
R	- Removals given in m³ or Todm o.b. (volume of fellings given in m³ or Todm u.b. (about 80 – 85 % of the fellings in m³ o.b.) without bark and felling residues, in the following text this parameter is used also as (round)wood production or yield)
T	- ton (1000 kg)
yr	- year

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1 Background and Objectives

BRED is the acronym for Biomass for greenhouse gas emission REDuction. This project is funded by the Environment and Climate research programme of the European Union. The project started in January 1998 and will last until December 1999.

A number of strategies have been proposed to reduce greenhouse gas emissions (GHGs). One important strategy is based on the introduction of more plant biomass as a substitute for fossil energy carriers and for materials. Biomass can be used to produce energy, e.g. heat, electricity or transportation fuels (called “bioenergy”), or it can serve as feedstock for synthetic organic materials and for structural materials such as timber (called “biomaterials”). Biomass can also be used in a sequence of both applications: first as a material, second as an energy source. The availability of biomass (bioenergy and biomaterial crops) in Western Europe is limited by the land availability and the biomass yields per square kilometre. This limits the potential of the biomass strategy for GHG emission reduction. The BRED project focuses on the cost-effective allocation of limited biomass resources for GHG emission reduction in order to assess its attractiveness. Competition with other strategies for GHG emission reduction is taken into account.

Starting from the EU policy goal for greenhouse gas emission reduction, the objective of the project is to analyse the optimal use of indigenous biomass for energy and materials "from cradle to grave" in the Western European (EU+EFTA) economy in order to achieve cost-effective greenhouse gas emission reduction on the long term (period 2000-2050). The goal is to provide a consistent and scientifically well founded set of recommendations for research, development and demonstration and investment policies for policy makers and for industry.

The following problems will be analysed:

1 Which prospective crops and prospective markets can be discerned for biomass in Western Europe for the period 2000-2050?

2 Which combination of bioenergy and biomaterials crops should European agriculture focus upon from the point of view of cost-effective GHG emission reduction policies?

3 Which conversion technologies, which markets and which biomass waste technologies must be developed?

4 How to compare the emission reduction potentials and the costs of bioenergy and bio-material options for GHG emission reduction to other technological improvement options that compete for the same product and service markets?

5 Should a biomass-for-carbon-storage or a biomass-for-energy-and-materials strategy be applied to the limited European land resources?

6 What is the impact of a changing energy and materials system configuration and different scenarios for energy prices, CO_2 storage, energy conservation, and renewables, on the future cost-effectiveness of biomaterial and bioenergy options for GHG emission reduction?

A systems modelling approach will be applied in the BRED study. The economic system is characterised by the energy and material flows and by the "technologies", that represent the conversion process of one material flow to another. Technologies are modelled as "black boxes", characterised by a linear relation between their physical inputs and outputs and by their costs. The analysis will be based on calculations with an extended version of a Western European integrated energy and materials systems model. The biomass technology database of the Western European MATTER 1.0 MARKAL [1] systems engineering model will be extended and improved based on detailed information regarding energy and material flows and future potential biomass applications.

1 D.J. Gielen, T. Gerlagh, A.J.M. Bos (1998): MATTER1.0. A MAKAL Energy and Materials System Model Characterisation. ECN-C—98-065. Netherlands Energy Research Foundation ECN, Petten, the Netherlands, September 1998.

The BRED project research tasks are:

1 Quantification of current biomass production and use in Europe

2 Assessment of land availability

3 Assessment of biomass yield and production costs for regions

4 Identification of options for substituting other materials

5 Techno-economic characterisation of material production and recycling options

6 Techno-economic characterisation of product assembly, utilisation and separation

7 Techno-economic characterisation of energy recovery and disposal options

8 Analysis of the information from the task 5-7 in the MARKAL analytical framework

This report is a product of task 1 and task 3. It focuses on the roundwood production and use in following European regions:

North:	Norway, Sweden, Finland, Denmark
Middle:	United Kingdom, Ireland, The Netherlands, Belgium, Luxembourg, Germany, France, Switzerland, Austria
South:	Spain, Portugal, Italy, Greece

2 Quantification of Current Roundwood Production and Use in Europe

2.1 Introduction

Chapter 2 is divided into the following three sections:

- Methodology
- Results
- Discussion

Data given in this report are based on the relevant literature and unpublished reports, or have been estimated on the base of expert knowledge after discussions with scientists and interviews with experts in the forestry and forest products sectors. The results obtained are shown in section 2.2 as well as in Annex 1/Tables 1 – 19. Section 2.3 contains discussions on the reliability of results obtained.

2.2 Methodology

2.2.1 General descriptions and definitions

In order to model the wood material and energy flows in MARKAL the first task is to establish the data structure base on the current roundwood production and use. For this purpose different statistic sources were used. The most useful data base for description of roundwood production was the FAO-Statistics [2]. These data are available as a yearbook, as files on disk and as internet information.

The data for production, exports, imports and consumption of roundwood and wood products are presented by countries (EU countries, Switzerland and Norway) and for the following items (definitions quoted word by word from FAO statistics, 1996):

[2] FAO (1996): Yearbook Forest Products 1983 – 1994. FAO Forestry Series No. 29, FAO Statistics Series No. 129. FAO, UN, ECE, Roma.

- SAWLOGS AND VENEER LOGS
  Sawnlogs, veneer logs and logs for sleepers. Logs whether or not roughly squared, to be sawn (or chipped) lengthwise for the manufacture of sawnwood or railway sleepers (ties). Single bolts and stave bolts are included. Logs for production of veneer, mainly by peeling or slicing. Match billets are included, as are special growth (burls, roots, etc.) used for veneers.

- PULPWOOD AND PARTICLES
  Pulpwood. Wood in the rough other than logs, for pulp, particleboard or fibreboard. Pulpwood may be barked or unbarked and may be in the form of roundwood or splitwood; it may include the equivalent of wood chips made directly from roundwood.

  Wood chips and particles. Wood that has been deliberately reduced to small pieces from wood in the rough or from industrial residues, suitable for pulping, for particleboard and fibreboard production, for fuelwood or for other purposes.

- FUELWOOD AND CHARCOAL
  Data on the production of these commodities are not reported for a number of countries but are known to be important in their total use of wood. Estimates for these countries are based on available survey data and are revised as new surveys become available. The annual change in production for these countries is estimated to be proportional to population change.

- OTHER INDUSTRIAL ROUNDWOOD
  Roundwood used for tanning, distillation, match blocks, poles, piling, posts, pitprops, etc.

- SAWNWOOD AND SLEEPERS
  Sawnwood, including sleepers, unplaned, planed, grooved, tongued, etc., sawn lengthwise or produced by a profile-chipping process (e. g. planks, beams, joist, boards, rafters scantlings, laths, boxboards, "lumber", etc.) and planed wood, which may also be finger-jointed, tongued or grooved, chamfered, rabbeted, V-jointed, beaded, etc. Wood flooring is excluded. With few exceptions, sawnwood exceeds 5 mm in thickness.

- VENEER SHEETS
  Thin sheets of wood with uniform thickness, rotary cut, sliced or sawn, for use in plywood, laminated construction, furniture, veneer containers, etc. With regard to the production the quantity given excludes veneer sheets used for plywood production within the country.

- PLYWOOD
  Plywood, veneer plywood, core plywood, including veneered wood, blockboard, laminboard and battenboard. Other plywood, such as cellular board and composite

plywood. Veneer plywood is plywood manufactured by bonding together more than two veneer sheets. The grain of alternate veneer sheets is crossed, generally at right angles. Core plywood is plywood whose core (i.e. central layer, generally thicker than the other plies) is solid and consist of narrow boards, blocks or strips of wood placed side by side, which may or may not be glued together. (This item includes veneered wood in sheets or panels in which a thin veneer of wood is affixed to a base, usually of inferior wood, by glueing under pressure.) Cellular board is plywood with a core of cellular construction, while composite plywood is plywood with the core or certain layers made of material other than solid wood or veneers.

- PARTICLEBOARD
  A sheet material manufactured from small pieces of wood or other ligno-cellulosic materials (e.g. chips, flakes, splinters, strands, shreds, shives, etc.) agglomerated by use of an organic binder together with one or more of following agents; heat, pressure, humidity, a catalyst, etc. (Flaxboard is included. Wood wool and other particleboards, with inorganic binders, are excluded).

- FIBREBOARD
  Fibreboard (fibre building board). A panel manufactured from fibres of wood or other ligno-cellulosic materials with the primary bond deriving from the felting of fibres and their inherent adhesive properties. Bonding materials and/or additives may be added. Fibreboard is usually flat-pressed, but it may also be moulded. Non-compressed includes insulating board with a censity of not more than exceedings 0.35 g/cm³ but not exceeding 0.50 g/cm³. Similar products made from pieces of wood, wood flour or other ligno-cellulosic material with added binders are excluded - as are, for example, boards of gypsum or other mineral material.

- CHEMICAL WOOD PULP
  Wood pulp, sulphite, except dissolving grades. Wood pulp obtained by mechanically reducing coniferous or non-coniferous wood to small pieces that are subsequently cooked in a pressure vessel in the presence of a bisulphite cooking liquor. Bisulphites such as ammonium, calcium, magnesium and sodium are commonly used. The two classes are bleached and unbleached.

  Wood pulp, sulphate (kraft) and soda, except dissolving grades. Wood pulp obtained by mechanically reducing coniferous or non-coniferous wood to small pieces that are subsequently cooked in a pressure vessel in the presence of sodium hydroxide cooking liquor (soda pulp) or a mixture of sodium hydroxide and sodium sulphite cooking liquor (sulphate pulp). The two classes are bleached and unbleached.

- MECHANICAL WOOD PULP
  Wood pulp obtained by grinding or milling coniferous or non-coniferous rounds, quarters, billets, etc. into fibres, or through refining coniferous or non-coniferous chips. Also called groundwood pulp and refiner pulp. It may be bleached or unbleached. This aggregate excludes exploded defibrated pulp, and includes chemi-mechanical and thermo-mechanical pulp.

- OTHER PULP
  Semi-chemical wood pulp. Wood pulp, chemi-mechanical and semi-chemical Wood pulp obtained by subjecting coniferous or non-coniferous wood to a series of mechanical and chemical treatments, none of which alone is sufficient to make the fibres separate readily. According to the order and importance of the treatment, such pulp is variously named: semi-chemical, chemi-groundwood, chemi-mechanical, etc. It may be bleached or unbleached.

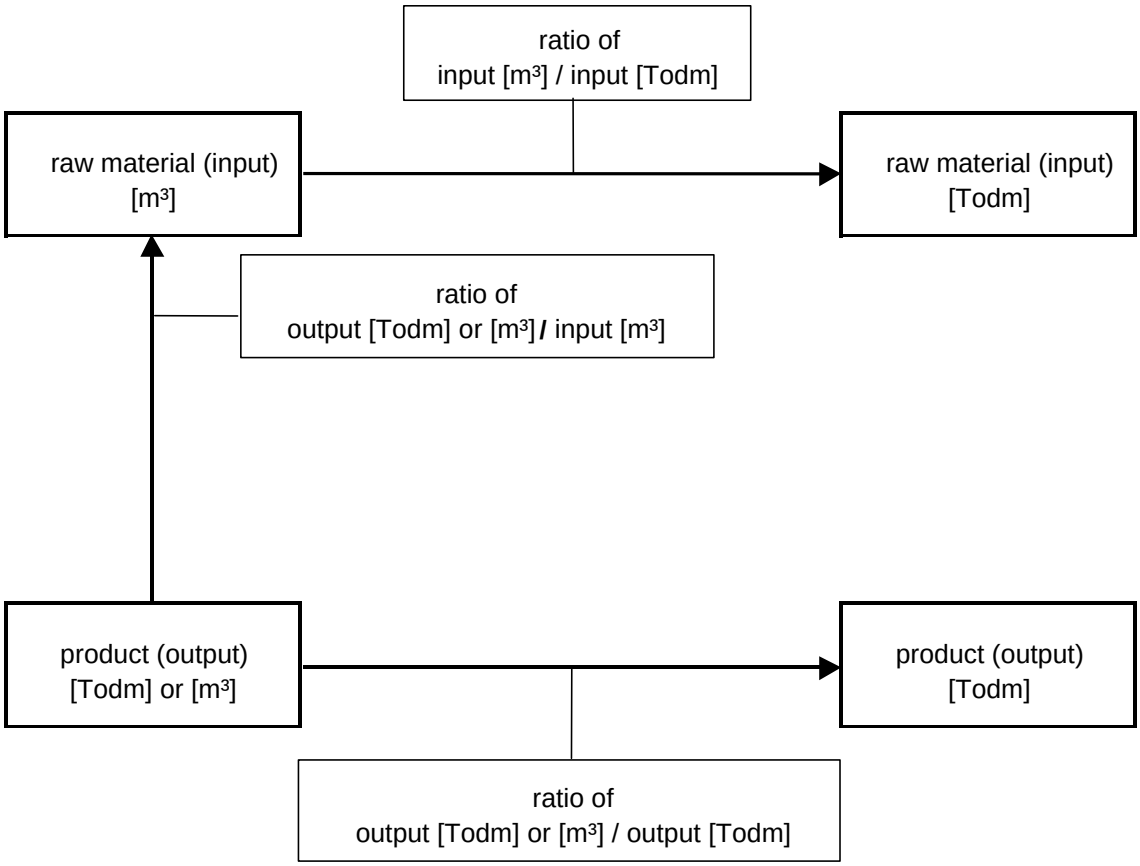
  Wood pulp, dissolving grades. Chemical pulp (sulphate, soda or sulphite) from coniferous or non-coniferous wood, of special quality with a very high alpha-cellulose content (usually 90 percent and over), readily adaptable for uses other than paper-making. These pulps are always bleached. They are used principally as a source of cellulose in the manufacture of products such as synthetic fibres, cellulosic plastic materials, lacquers and explosives.

- RECOVERED PAPER
  Waste and scrap of paper or paperboard. This includes paper and paperboard which has been used for is original purpose and residues from paper conversion. This includes waste and scrap collected for re-use as a raw material for the manufacture of paper and related products.

2.2.2 Sources and assumptions for assessment of wood supply and use in Europe

The supply oriented data in the FAO-Statistics split up the harvested amounts of roundwood into different sectors of use. This, however, does bot reflect the real situation. The roundwood used by the wood industry sectors does not necessarily correspond to the FAO categories. Due to the lack of data the fraction of total roundwood used for different purposes had to be derived from the more reliable production data for significant wood products. First the raw material input for sawnwood and sleepers, veneer sheets, plywood, particleboard, fibreboard, different types of wood pulp and other products was determined, using average conversion factors. Furthermore the input in [m³] was transformed by the average conversion factor of 520 kg odm / m³ to a raw material input in [Todm]. Finally the production in [m³] units was transformed into [Todm] output (see Table 1 and Diagram 1).

Diagram 1: Conversion of raw material (input) and production (output) into Todm



The following literature sources were used for data collection and calculation of conversion factors of various wood products: German-Statistics 1997, UN/ECE 1996, FESYP Annual Report 19995/96, ZMP 1996, other publications and reports related to the subjects of the BRED study.

Factors for converting raw materials into various products are given in Table 1.

Table 1: Average conversion factors for calculation of raw material input and production (output) into [Todm] unit [3]

Products	**Ratio**			
	Output (product) / Input (roundwood)		Output (product) / Output (product)	
Sawnwood+sleepers	0.54	m³/m³	1.92	m³/Todm
Sawnwood (NC)	0.84	m³/m³	1.92	m³/Todm
Sawnwood (C)	0.51	m³/m³	1.92	m³/Todm
other wood pulp	0.19	Todm/m³	1.00	Todm/Todm
Dissolving wood pulp	0.18	Todm/m³	1.00	Todm/Todm
Semi-chemical wood pulp	0.20	Todm/m³	1.00	Todm/Todm
Mechanical wood pulp	0.49	Todm/m³	1.00	Todm/Todm
Chemical wood pulp	0.18	Todm/m³	1.00	Todm/Todm
Bleached sulphite pulp	0.20	Todm/m³	1.00	Todm/Todm
Bleached sulphate pulp	0.18	Todm/m³	1.00	Todm/Todm
Unbleached sulphate pulp	0.18	Todm/m³	1.00	Todm/Todm
Unbleached sulphite pulp	0.20	Todm/m³	1.00	Todm/Todm
Particle board	0.62	m³/m³	1,47	m³/Todm
Veneer sheets+Plywood	0.47	m³/m³	1.92	m³/Todm
Veneer Sheets	0.49	m³/m³	1.92	m³/Todm
Plywood	0.47	m³/m³	1.92	m³/Todm
Fibreboard	0.48	m³/m³	1.24	m³/Todm

FAO-Statistics do not contain data concerning the production and consumption of wood in the end use sector, e.g. windows, doors, wood bridges etc.

To solve the problem regarding the lack of reliable statistical data sources the results of different studies on inventory and life cycle assessment for forest products were

[3] Based on interviews with experts of BFH and Hamburg University

used to estimate the volume of products for end use (SCHARAI-RAD et AL. 1996[4], ADEBAHR, S. 1995[5], HASCH, J. 1995[6], IÖW 1991[7], RISTL 1996[8], ZIMMER and WEGENER 1996[9]).

2.2.3 Sources and assumptions for assessment of wood consumption in the building sector

For the calculation of the amount of sawnwood and panels used in residential and non-residential buildings the study of KROTH, KOLLERT, FILIPI (1991) [10] and the report of UN/ECE (1996) [11] provided useful data.

Table 2: Average Shares of Output and Residues for Various Products

Products	**share of output**	**share of residues**
Construction residential buildings	0.91	0.09
Completion residential buildings	0.78	0.22
Construction non-residential buildings	0.91	0.09
Completion non-residential buildings	0.78	0.22
Formwork	0.70	0.30
Packaging	0.81	0.19
Furniture	0.73	0.27
Parquet	0.50	0.50
Other end use sectors	0.64	0.36

[4] SCHARAI-RAD, M., ZIMMER, B., HASCH, J. (1996): Grundlagen für Ökoprofile und Ökobilanzen in der Forst- und Holzwirtschaft

[5] ADEBAHR, S. (1995): Stoff- und Energiebilanzen für Konstruktionsholz. Diplomarbeit an der Universität Hamburg, Fachbereich Biologie

[6] HASCH, J. (1995): Sachbilanzen als Grundlage der Ökobilanzierung in der Holzfensterindustrie. Diplomarbeit an der Universität Hamburg, Fachbereich Biologie

[7] IÖW (1991): Ökobilanz Sägewerk Steiner; Pilotprojekt in der Sägeindustrie. Schriftenreihe des Instituts für ökologische Forschung Wien (IÖW) 5: 66 S., Wien

[8] RISTL, M. (1996): Erstellung einer Sachbilanz von Brettschichtholz als Grundlage für eine Ökobilanzierung. Diplomarbeit an der Universität Hamburg, Fachbereich Biologie

[9] ZIMMER, B.; WEGENER, G. (1996): Stoff- und Energieflüsse vom Forst zum Sägewerk. Holz als Roh- und Werkstoff

[10] KROTH, W.; KOLLERT, W and FILIPI, M. (1991): Analyse and Quantifizierung der Holzverwendung in Bauwesen. Ludwig – Maximilian – Universität München

[11] ECONOMIC COMMISSION FOR EUROPE (1996): Annual bulletin of housing and building statistics for Europe and North America

Complete data regarding the consumption of timber and wood based panels in different sub-sectors of forest products are unfortunately not available. In order to find out reliable results on wood consumption experts of Federal Research Centre for Forestry and Forest Products Hamburg (BFH) were interviewed. The results achieved show that the sub-sector building, incl. window/doors, consumes at least 50 % of the supply followed by furniture industry (23 %), packaging (8 %), formwork (7 %), flooring (2 %) and other uses (10 %).

Further investigations on wood consumption which were based on study of literature, discussion with the experts of BFH, and contacts with industry and trade organisations have more and less confirmed that annually approximately 50-60 % of the wood supply are consumed in the building industry. The furniture industry is the second most important consumer (20-25 %) followed by packaging, formwork and flooring industry.

For calculation of wood consumption in residential and non-residential buildings the study of KROTH et AL. (1991)[12] and statistics of UNECE (1996) provided very useful data.

KROTH et AL. report on the amount of timber and wood based panels used for construction and completion of residential and non-residential buildings in Germany (s. Table 3, Table 4 and Table 7).

Table 3: *Wood consumption in wooden houses[1)] related to 1000 m³ space volume[2)]*

	Sawnwood [m³]		Particleboard	Other panels	Parquet	Total
	Construction	Completion	[m³]	[m³]	[m³]	[m³]
1-family dwellings	29.2	20.5	0.7	0.7	0.8	51.9
2-family dwellings	33.9	29.5	0.3	0.6	0.4	64.7

1) Houses in which wood is the dominant material
2) A house of 1000 m³ volume

[12] KROTH, W.; KOLLERT, W and FILIPI, M. (1991): Analyse and Quantifizierung der Holzverwendung in Bauwesen. Ludwig – Maximilian – Universität München

Table 4: Wood consumption in conventional houses[1)] related to 1000 m³ space volume[2)]

	Sawnwood [m³]		Particleboard	Other panels	Parquet	Total
	Construction	Completion	[m³]	[m³]	[m³]	[m³]
1-family dwellings	10.2	10.3	0.8	0.5	0.2	22
2-family dwellings	9.9	9.3	0.9	0.6	0.3	21
Multi-family houses	6.4	3.8	0.5	0.5	0.2	11.4

1) Conventional houses are houses made from various materials such as wood, concrete, bricks, stones etc.
2) A house of 1000 m³ volume

Wood consumption in residential buildings

As indicated in Tables 3 – 4 the buildings are divided into the following two categories:

- Wooden houses in which wood dominates as building material.
- Conventional houses that are made from various materials such as stone, concrete, bricks, timber, etc.

Moreover, the figures in the above mentioned tables are related to 1000 m³ space volume and can not be used directly as basic data for the calculation of wood consumption in the building sector. The most important step is, therefore, to calculate the average space volume of dwellings in Europe. Based on Diagram 2 and German Standard DIN 277 the average space volume of dwellings in Northern, Western and Southern Europe amounts to 769 m³, 727 m³ and 544 m³ respectively (compare also with Table 5).

Figures showing the number of new buildings constructed in 1994 subdivided into flats, houses and other is given in

Table 6. This subdivision is necessary due to the different amount of wood and wood panels used in different types of residential units (house, flats, other).

Tables 3 – 6 enable the calculation of wood consumption (incl. wood based panels) in residential buildings.

Diagram 2: Assumed average size of dwellings

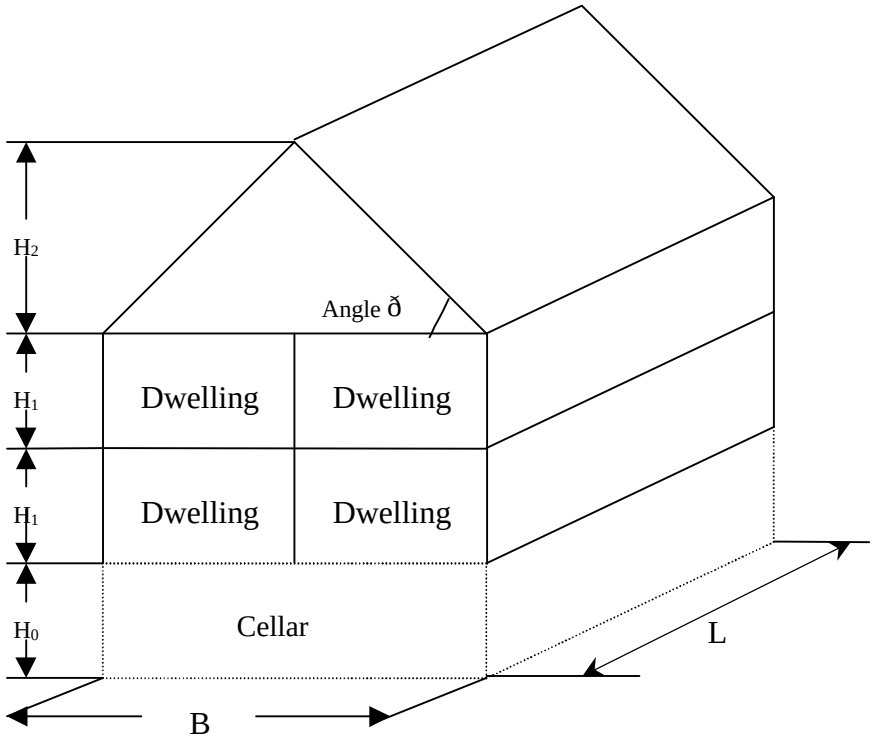


Table 5: Average size[1)], dimensions and space volume of dwellings in three European regions (see Diagram 2)

Region	Angle	Average dimensions of existing dwellings						Volume
		Height [m]			Length [m]	Width [m]	Places of other uses[3)]	Average value
	ð	H_0	H_1	H_2	L	B/2	[m³]	[m³]
North	~ 35°	1.20[2)]	2.75	4.9	13	7	3 * 10 * 2.9	670
Middle	~ 30°	2.40	2.75	4.0	12	7	5 * 9 * 2.8	727
South	~ 20°	1.20[2)]	2.80	3.0	10	8	5 * 8 * 2.6	544

1) Based on data given by UNECE 1996

2) For North and South Europe it is assumed that 50 % of residential buildings do not have cellar. Therefore, the normal height of 2.40 was cut in halves.

3) Garages, stores, etc.

Table 6: Number of new buildings constructed in 1994[1)] subdivided into flats and houses

Country	**Dwellings constructed 1994**						
	Houses		Flats		Other		**Total**
	[1000]	[%]	[1000]	[%]	[1000]	[%]	**[1000]**
Europe North	43.1	54.6	35.7	45.2	0.2	0.2	79
Europe Middle	1171.7	85.4	168.9	12.3	31.4	2.3	1372
Europe South	192.0	39.0	298.0	60.6	2.0	0.4	492
Total	**1406.8**	**72.4**	**502.6**	**25.9**	**33.6**	**1.7**	**1943**

Wood Consumption in Non-residential Buildings

With regard to the consumption of wood and wood based panels Kroth et al. categorised the non-residential buildings into “Buildings looking like residential buildings”, “Industrial buildings” and “Agricultural buildings”. The results achieved by their study are found in Table 7.

The number of non-residential buildings completed in 1994 or 1993 are given in Table 8. For some countries data for 1994 were missing so that data for previous year were used.

Table 9 indicates the number of units of non-residential buildings completed by type in 1994 or 1993. 1 unit includes 1000 m^3 space volume.

In case of buildings looking like residential buildings Kroth et al. distinguished between conventional and wooden houses. Therefore, figures given in Table 10 were also used for calculation of wood consumption in non-residential buildings.

Table 7, Table 8,

Table 9 and Table 10 provide the necessary data for the calculation of wood and wood based panels in non-residential buildings.

Table 7: Wood consumption in non-residential houses[1)] related to 1000 m³ space volume

Conventional houses: Houses made from various materials such as wood, concrete, bricks, stones, etc.						
	Sawnwood [m³]		Particleboard	Other panels	Parquet	Total
	Construction	Completion	[m³]	[m³]	[m³]	[m³]
Buildings looking like residential buildings[1)]	6.8	5.1	0.5	0.4	0.5	13.3
Industrial buildings	3.6	1.9	0.3	0.2	0.1	6.1
Agricultural buildings	11.9	4.4	-	0.2	-	16.5
Wooden houses: Houses in which wood is the dominant material						
Buildings looking like residential buildings	27.5	26.1	2.3	0.7	0.9	57.5

1) KROTH et AL. 1991

Table 8: Number of new non-residential buildings completed by type, 1994 or 1993[1)]

Region	Number total	Building by type (as % of the total number)		
		Similar to residential build.	Industrial	Other (agricultural. etc.)
Europe North	101469	10.6	7.5	81.9
Europe Middle	185305	31.1	17.8	51.1
Europe South	72492	19.3	12.9	67.8

1) Due to the lack of complete data for 1994 the authors had to take data for previous year.

Table 9: Total number and the number of units of non-residential buildings completed by type in 1994 or 1993[1)] - 1 unit includes 1000 m³ space volume

Country	Number total	Average space volume [m³]	Number of units Total/1000 m³	Building by type Number of units		
				Similar to residential build.	Industrial	Other
Europe North	101469	757	76830	8142	5762	62924
Europe Middle	185305	4556	844270	262568	150280	431422
Europe South	72492	2031	147200	28410	18988	99802

Table 10: The share of wooden and conventional houses for buildings similar to residential buildings[1)]

Region		Wooden houses		Conventional houses	
Europe North	8142	30 %	2443	70 %	5699
Europe Middle	262568	5 %	13128	95 %	249440
Europe South	28410	-	-	100 %	28410

1) Estimate

Additional remarks

The results of KROTH et AL. study (1991) cover more or less the situation in Germany. However, it was assumed that in most European countries concerned a similar situation does exist. The reasons for this assumption are as follows:

- Compared with Middle and South Europe more solid wood and wood based panels are used for construction and completion of residential buildings in North Europe. However, the relative volume of wood and panels used in different parts of buildings might be the same all over Europe.
- The share of wooden houses is in North Europe more and in South Europe less than in Middle Europe. However, the volume of timber and other wood based material used in the building related to a certain unit (e.g. 1000 m³ space volume) might be the same.

- For the calculation of space volume the German Standard DIN 277, May 1973 and the statistics given by UNECE (1996) were very useful sources. But it was assumed that Diagram 2 represents the average residential buildings in Europe.
- Discussions with experts resulted to the assumption that the ratio of wooden houses to those constructed mainly from other materials could be as follows:
  - Northern Europe 50 % wooden houses and 50 % other houses
  - Middle Europe 10 % wooden houses and 90 % other houses
  - Southern Europe 0 % wooden houses and 100 % other houses
- Flats are not made completely from wood.
- For North and South Europe it is assumed that 50 % of residential buildings do not have a cellar
- For the conversion of m^3 to Todm the following factors were used:

Coniferous:	465 kg odm/m^3
Non-coniferous:	670 kg odm/m^3
Average:	520 kg odm/m^3

2.3 Results

According to the FAO-Statistics the analysed countries in 1994 had a roundwood production (roundwood removals from the forests) of 138.7 M Todm or 266.7 M m³. By considering the net roundwood export-import, the total volume of roundwood supply amounts to 155.7 M Todm. The roundwood production includes 69 M Todm sawlogs and veneerlogs, 46.7 M Todm pulpwood and particles, 19.6 M Todm fuelwood and charcoal, and 3.4 M Todm so called "other industrial roundwood". As described in chapter "Methodology" such differentiated figures do not indicate the real consumer sector, because re-sorting is taking place.

The major industrial wood products in Europe are sawnwood, fibreboards, particleboards, veneer sheets and plywood, and different types of pulp.

The sawnwood and sleepers production and consumption in West Europe in 1994 amounted to 36.5 M Todm (70.1 M m³) and 40.6 M Todm (78.0 M m³) respectivly. Details on production, import, export and apparent consumption in the three regions (North, Middle, South) is shown in Table 6 of the

Annex 1.

The volume of veneer sheets and plywood production in total amounts to 2.1 M Todm; the consumption amounts to 3.6 M Todm. More details in [1000 m³] are given in Tables 7 and 8 of

Annex 1.

Figures for particleboards and fibreboards (Tables 9 and 10 of

Annex 1) show that for both products the production almost equals the consumption. However, fibreboards with almost 3.0 M Todm are less important than particleboards with an annual consumption of nearly 16.1 M Todm.

The detailed results from the FAO-Statistics are given in

Annex 1.

Sawnwood is used as structural timber as well as for furniture production, packaging, formwork, parquet and some other uses. As shown in Table 11 the building sector is the main user of sawnwood followed by furniture, packaging, formwork and parquet. Other users consume 6.8 MTodm sawnwood.

The major users of panels are the furniture industry with 11.8 M Todm and the building sector with 7.1 M Todm. Other users, packaging and formwork follow with 1.4 M Todm, 1.4 M Todm and 0.7 M Todm respectively.

Table 11: Volume of Panels and Sawnwood Consumption by End Use Sector Products and Resulting Residues

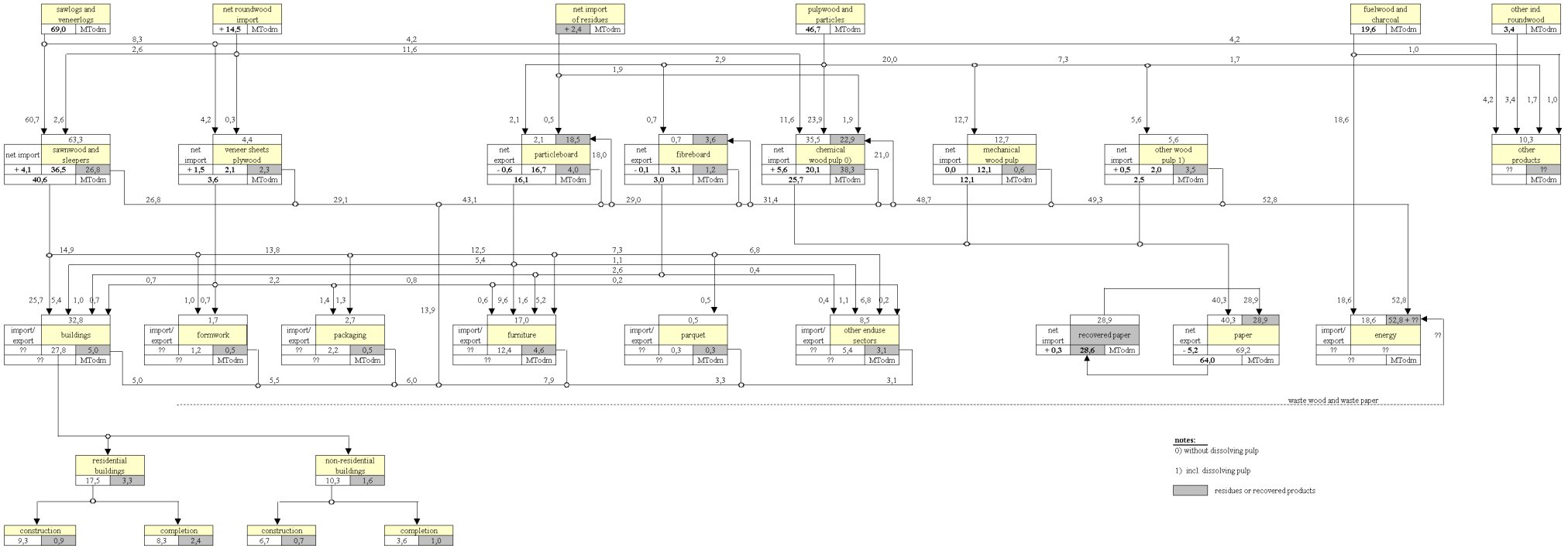
Sectors	**Particleboard [Mtodm]**	**Fibreboard [MTodm]**	**Veneer and Plywood [MTodm]**	**Panels in total [MTodm]**	**Sawnwood [MTodm]**
Buildings	5.4	1.0	0.7	**7.1**	25.7
Furniture	9.6	1.6	0.6	**11.8**	5.2
Parquet	-	-	-	**-**	0.5
Packaging	-	-	1.4	**1.4**	1.3
Formwork	-	-	0.7	**0.7**	1.0
Other uses	1.1	0.4	0.2	**1.7**	6.8
Total	**16.1**	**3.0**	**3.6**	**22.7**	**40.6**

Based on the FAO-Statistics and literature sources the flow-scheme "Roundwood – semifinished wood products - products for end use" in Europe for the year 1994 has been constructed (Diagram 3).

The bold figures in the flow-scheme are taken from the FAO-statistics and can be checked by the tables in the

Annex 1.

Diagram 3: Flow-scheme "Roundwood – semifinished wood products – products for end use" in Europe for the year 1994



2.4 Discussion

Diagram 3 shows the material flow from the roundwood production to the enduse sector, including the internal flows and back flows of residues. The first level of the flow-scheme is forestry, where logs and other types of roundwood are produced. At the second and third level where semi-finished and finished products are produced considerable amounts of residues are generated.

Actually, for the illustration of material flow it is necessary to calculate the apparent consumption which is based on production, import and export. In case of production and export the production sites are located within the study area so that the ratio of input (raw wood, panels, semi-finished products) to output (semi-finished and finished products) must be known. Otherwise it is impossible to calculate the volume of residues. In case of import, however, the production sites are outside of study area and, consequently, additional calculations regarding the share of residues are not necessary.

All figures in the first and second level are taken from the official statistics such as FAO Yearbook, UN/ECE publications, FESYP, national statistics and studies conducted in the countries concerned. Consequently, they are regarded as reliable and more and less exact. The uncertainty might be between +/- 5 % to 10 %.

The figures at the third level, however, are generated on the following basis:

- Results derived from the available data such as statistics and studies mentioned above,
- Estimations based on discussions and interviews with experts in the fields of forestry and forest products,
- Inquiries to the organisations and associations involved,
- Reasonable assumptions which are more and less acceptable for the three European regions (North, Middle and South).

Therefore, the figures shown at third level are sufficiently exact, although deviations from the reality are unavoidable. The uncertainty might be around +/- 20 %. The inaccuracy is related to:

- the lack of data for imports and exports,

- insufficient statistics about consumption in building, furniture industry, packaging, formwork, parquet, and other uses,
- incomplete information on the flow of residues to the places of material or thermal utilisation.

The question marks “??” given in the flow-scheme are the consequence of these shortages. The flow-scheme as whole is a useful overview and illustrates the material flow in the forestry and forest products sector in Europe.

3 Assessment of Roundwood Yield and Production Costs for Regions

3.1 Methodical Approach

Annual yield in forestry strongly depends on age and species structure. It can not be regarded constant over time. Furthermore, the annual yield in forestry can only be influenced by technical progress slowly in the long term.

For this reason yield and also production costs calculations must be based on a scenario analysis of the development of the present age class structure. Such kind of analysis was carried out by the ETTS V-Study which is partly cited word by word below:

“This study is based on information provided by ... countries. Countries were invited to give their own forestry forecasts to the ECE-timber-secretariat ... based on an intimate knowledge of their countries’ forestry situation and plans. The estimates of the secretariat were based on growth and felling figures which were presented in forest resource assessment 1990.

The scenarios on development of forest resources, growth and fellings are based on the following relationship of these variables: Growing stock at the beginning of a given period plus net annual increment minus fellings during the period equals the growing stock at the beginning of the next period.

...

It was assumed that net annual increment and the forest area for these countries would remain constant.

...

Under normal natural conditions, forest fires, windthrows, fungus and insect infestations often destroy large forest areas, but they are impossible to forecast and thus they were not taken into account when scenarios were made.

The environmental policies will not have any major effect on the timber harvested on country level, although some local forests will be transferred into nature conservation areas. Cutting restrictions are not going to play any significant role.

The effects of acid rain are visible in the forests, although many countries are not yet severely affected. There are no quantitative data on the effects of airborne pollutants or climate change. The change in forest ownership structure will not have any significant influence on the forest resources.

It thus appears that future changes in the European forest resource, and especially the level of removals, are not primarily influenced by developments in the roundwood markets, or even by the international competitiveness of the country concerned (although this may well set an upper limit on prices), rather by the structure of forest stands and by the forest policy, i.e.:

- age class structure;
- long term programmes for forest expansion (e.g. UK, Ireland, Portugal, Spain) of forest improvement (e.g. France, Finland), or, on the other hand withdrawal of forests from wood production, e.g. for nature reserves;

the structure of subsidies, fiscal incentives etc." [13]

The data in the ETTS V - Study are structured by tree species groups (coniferous and non coniferous) but not by assortments. In order to quantify the assortment structure of timber the structure of the FAO-Statistic data set for the year 1994 was used. Figures for the year 1995 were linearly interpolated.

To estimate the average timber prices and the roundwood production costs for the year 1994 the FAO contact persons in the West European countries were asked for an expert estimation. Finland, Switzerland, Denmark and UK have responded.

A calculation of the following costs elements:

- harvesting and skidding,
- afforestation,

13 PAJUOJA, H. (1995): The Outlook for the European Forest Resources and Roundwood Supply. ETTS V Working Paper. UN-ECE/FAO Timber and Forest Discussion Papers. UN, New York and Geneva.

- forest conservation,
- forest protection,
- management

was carried out for Germany in order to get a better basis for assessments of production costs in the other countries.

Various MARKAL data sheets have been worked out to describe the different forest technologies, which are structured by the three regions, coniferous and non-coniferous species and by management types (conventional forestry and forestry after afforestations). Because of lack of data accessibility a lot of parameters in the data sheets had to be estimated based on various assumptions.

Firstly the forest land input was calculated. As database for this calculation the results of the ETTS V study were used. Based on the assumption that the increase of forest area over time given in the ETTS V study is mainly a result of afforestions the surplus of forest land was defined as afforestated land. Thus the forest land managed conventionally was considered as constant over time on the level of 1990. The removals from the afforestation area were calculated based on a yield model, adapted to the three regions by the level of removals, which are given for the total area of the region in the ETTS V study. The quantitity of removals from conventional forestry results as the difference between total removals and removals from afforestations.

The energy input for forest production was taken from research results about life cycle assessments in forestry [14]. The energy input was differentiated into coniferous and non coniferous tree species and assortment groups (industrial roundwood and sawlogs) and adapted to the regions.

Input of fertilisers for conventional forestry were assumed negligible.

The input of labour and investments into the forest production process was estimated on basis of different literature sources for representative countries. It is necessary to underline that costs for afforestation as well as for reforestation in forestry are not a

part of investments but a part of annual production costs. Therefore, the figures for investment given in the MARKAL data sheets show the annual average investments in machinery and technical equipment.

As mentioned before for the elaboration of cost data a special inquiry to the FAO statistic coordinators was organised. The results of this inquiry were taken as a base for the calculation of the cost input data for the MARKAL model. For structuring costs into variable and fixed costs a detailed forest cost analysis for Germany was used (see ANNEX 2).

All given cost data contain the total operation costs including cost for labour and energy. Data regarding physical input (italic figures in the data sheets) are only informative and should not be used in the MARKAL modelling process to avoid double counting.

Based on this approach all input data were related to the unit Todm. In order to convert these data into Joule the lower heating value of wood (19 MJ/kg odm) was used (Kollmann, Coté 1968)[15].

The calculation results are laid down in the MARKAL data sheets shown in ANNEX 4.

3.2 Results

3.2.1 Assessment of Yield for Regions

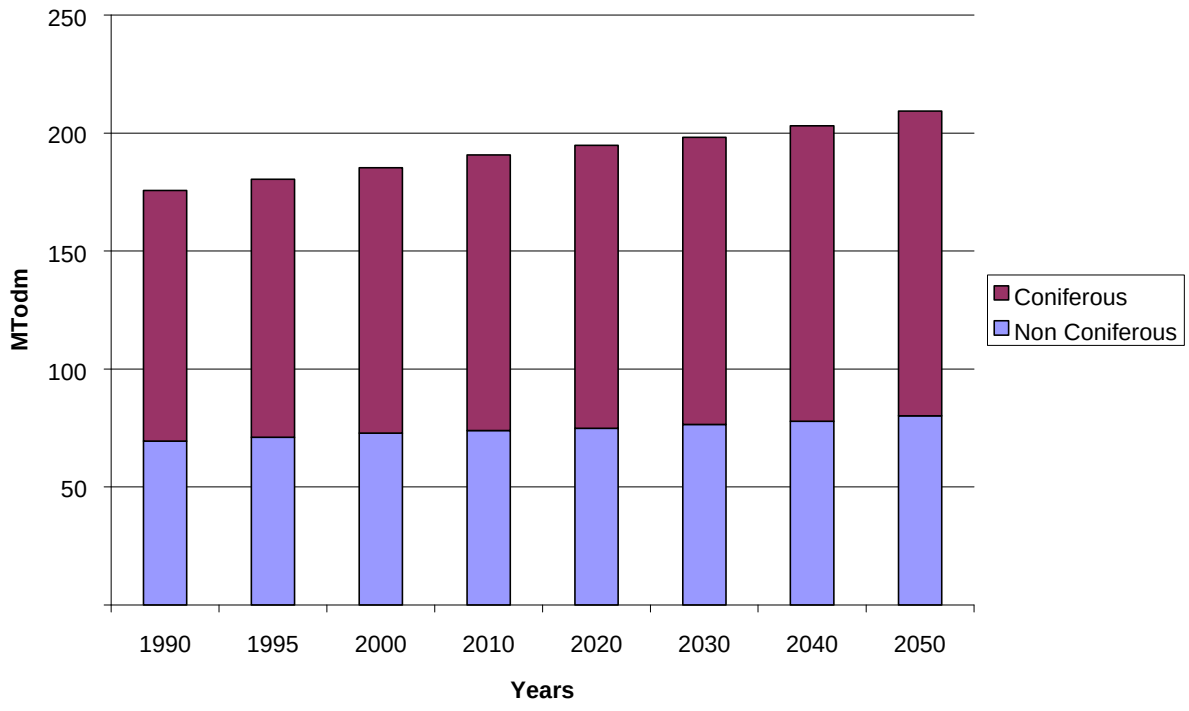
For 1995 the ETTS V-Study figures out a roundwood yield of 180 M Todm roundwood for all analysed countries, all tree species groups and all assortments. It is necessary to consider the differences between definitions for roundwood production in FAO-Statistics: **m³ under bark (m³ u.b.)** and for roundwood yield in the ETTS V- Study: **m³ over bark (o.b.)**. Based on the traditional knowledge in wood measuring (see for example German yield tables) roundwood volume in m³ o.b. can be transformed into m³ u.b. A rough transformation leads to a value of 143 M Todm (1995, all analysed countries). The data bases of ETTS V-Study and of FAO-Statistics are comparable.

[14] SCHWEINLE J. (1996): Analyse und Bewertung der forstlichen Produktion als Grundlage für weiterführende forst- und holzwirtschaftliche Produktlinien – Analysen. Mitteilungen der BFH Nr. 184, 123 S.

For the year 2000 a roundwood yield of 185 M Todm is estimated and for the year 2050 about 210 M Todm. The yield of coniferous wood is growing faster than the yield of non-coniferous wood (see Table 12).

Based on data given in Table 12 the weighted density of dry wood is around 520 kg/m³. Consequently 1 Todm corresponds to 1,92 m³ odm (compare also with Chapter 2.1).

Diagram 4: Estimation of Roundwood Yield in Analysed Countries by Tree Species Groups



Nearly half of the whole roundwood yield are sawlogs and veneer logs. one third pulpwood and particles. The assortment is more or less constant over time.

Detailed results are shown in Table 12.

[15] Kollmann F.F.P.; Coté W.A. (1968) Principles of Wood Science and Technology, Part I Solid Wood. Springer-Verlag Berlin, Heidelberg, New York

Table 12: Outlook for Roundwood Yield (felling o.b.) of Analysed Countries in M Todm for Regions and Years

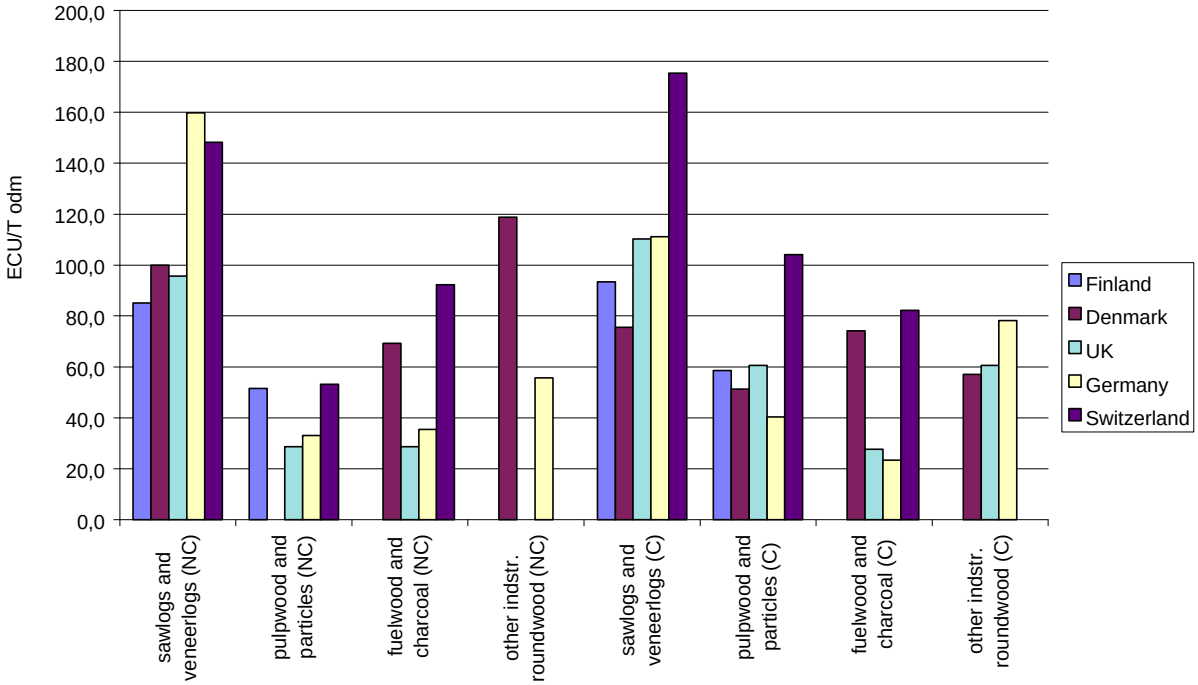
Region	Years	Non-coniferous and coniferous					Non-coniferous					Coniferous				
		Total	Sawlogs, Veneer sheets	Pulpwood Particles	Fuelwood Charcoal	Oth. ind. Round-wood	Total	Sawlogs, Veneer sheets	Pulpwood Particles	Fuelwood Charcoal	Oth. ind. Round-wood	Total	Sawlogs, Veneer sheets	Pulpwood Particles	Fuelwood Charcoal	Oth. ind. Round-wood
North	1990	67.218	29.528	28.630	7.945	1.116	17.271	2.556	8.152	6.097	466	49.948	26.972	20.478	1.848	649
	1995	66.923	29.473	28.493	7.849	1.108	17.003	2.516	8.026	6.002	459	49.920	26.957	20.467	1.847	649
	2000	66.629	29.419	28.355	7.754	1.100	16.736	2.477	7.899	5.908	452	49.893	26.942	20.456	1.846	649
	2010	67.124	29.624	28.568	7.822	1.109	16.894	2.500	7.974	5.964	456	50.230	27.124	20.594	1.859	653
	2020	67.230	29.681	28.612	7.827	1.111	16.896	2.501	7.975	5.964	456	50.333	27.180	20.637	1.862	654
	2030	67.431	29.595	28.725	7.991	1.120	17.393	2.574	8.209	6.140	470	50.038	27.021	20.516	1.851	650
	2040	67.398	29.515	28.721	8.040	1.122	17.551	2.597	8.284	6.195	474	49.847	26.917	20.437	1.844	648
	2050	67.686	29.681	28.838	8.042	1.125	17.523	2.593	8.271	6.186	473	50.163	27.088	20.567	1.856	652
Middle	1990	85.713	44.245	22.511	16.545	2.413	37.631	14.337	10.010	11.929	1.355	48.083	29.908	12.502	4.616	1.058
	1995	90.338	46.734	23.723	17.344	2.537	39.238	14.950	10.437	12.438	1.413	51.100	31.784	13.286	4.906	1.124
	2000	94.962	49.223	24.935	18.143	2.661	40.845	15.562	10.865	12.948	1.470	54.117	33.661	14.070	5.195	1.191
	2010	98.851	51.564	25.948	18.587	2.751	41.166	15.684	10.950	13.050	1.482	57.685	35.880	14.998	5.538	1.269
	2020	101.857	53.334	26.732	18.967	2.823	41.578	15.841	11.060	13.180	1.497	60.278	37.493	15.672	5.787	1.326
	2030	104.024	54.546	27.299	19.300	2.879	42.144	16.057	11.210	13.360	1.517	61.880	38.489	16.089	5.940	1.361
	2040	107.765	56.750	28.275	19.772	2.968	42.656	16.252	11.346	13.522	1.536	65.109	40.498	16.928	6.250	1.432
	2050	112.384	59.264	29.485	20.545	3.090	44.144	16.819	11.742	13.994	1.589	68.240	42.445	17.742	6.551	1.501
South	1990	22.693	7.621	7.069	6.702	1.302	14.546	2.415	5.179	6.197	756	8.147	5.206	1.890	505	546
	1995	23.184	7.773	7.225	6.857	1.330	14.888	2.471	5.300	6.342	774	8.296	5.301	1.925	514	556
	2000	23.675	7.925	7.381	7.011	1.358	15.230	2.528	5.422	6.488	792	8.445	5.397	1.959	524	566
	2010	24.664	8.273	7.685	7.291	1.415	15.830	2.628	5.636	6.744	823	8.834	5.645	2.050	548	592
	2020	25.738	8.671	8.010	7.579	1.478	16.438	2.729	5.852	7.003	855	9.300	5.942	2.157	577	623
	2030	26.738	9.050	8.310	7.842	1.537	16.989	2.820	6.048	7.237	883	9.750	6.230	2.262	604	653
	2040	27.878	9.499	8.648	8.128	1.604	17.580	2.918	6.259	7.489	914	10.298	6.581	2.389	638	690
	2050	29.261	9.976	9.075	8.526	1.684	18.439	3.061	6.564	7.855	959	10.822	6.915	2.511	671	725
Total	**1990**	**175.625**	**81.393**	**58.210**	**31.191**	**4.830**	**69.448**	**19.308**	**23.340**	**24.222**	**2.577**	**106.177**	**62.085**	**34.870**	**6.969**	**2.253**
	1995	**180.445**	**83.980**	**59.441**	**32.050**	**4.975**	**71.129**	**19.938**	**23.763**	**24.783**	**2.646**	**109.316**	**64.042**	**35.678**	**7.267**	**2.329**
	2000	**185.266**	**86.566**	**60.672**	**32.908**	**5.119**	**72.811**	**20.567**	**24.186**	**25.344**	**2.714**	**112.455**	**65.999**	**36.486**	**7.565**	**2.405**
	2010	**190.639**	**89.461**	**62.201**	**33.701**	**5.275**	**73.890**	**20.812**	**24.560**	**25.757**	**2.761**	**116.748**	**68.649**	**37.642**	**7.944**	**2.514**
	2020	**194.824**	**91.686**	**63.353**	**34.373**	**5.411**	**74.913**	**21.071**	**24.887**	**26.147**	**2.808**	**119.911**	**70.616**	**38.467**	**8.226**	**2.604**
	2030	**198.192**	**93.191**	**64.334**	**35.133**	**5.535**	**76.525**	**21.451**	**25.467**	**26.736**	**2.870**	**121.668**	**71.740**	**38.866**	**8.396**	**2.665**
	2040	**203.041**	**95.764**	**65.644**	**35.940**	**5.694**	**77.786**	**21.768**	**25.889**	**27.206**	**2.924**	**125.255**	**73.996**	**39.755**	**8.733**	**2.770**
	2050	**209.331**	**98.921**	**67.397**	**37.112**	**5.900**	**80.106**	**22.473**	**26.578**	**28.034**	**3.021**	**129.224**	**76.448**	**40.820**	**9.078**	**2.878**

3.2.2 Assessment of Production Costs for Regions

Table 1 to Table 5 of ANNEX 2 indicate the results of expert estimation of average timber prices and production costs for roundwood. The data for production are taken from the FAO-statistics in m³ under bark. The quotations for calculation in ECU are given in Table 6 of ANNEX 2.

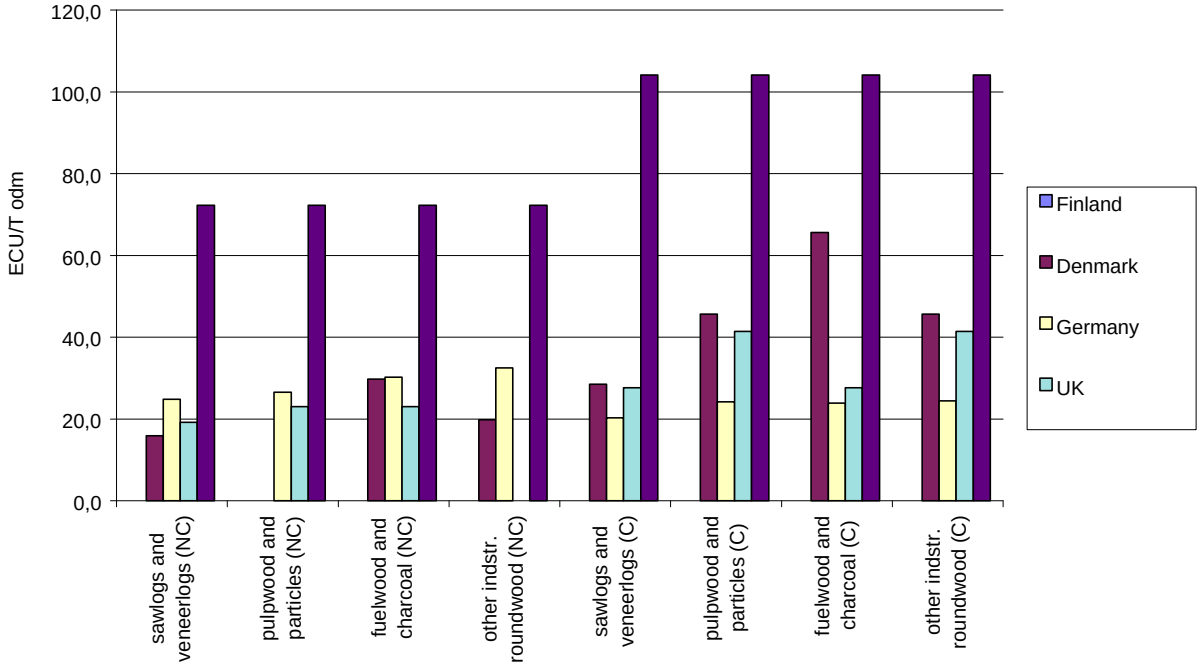
Prices are given for different sorts of roundwood along the forest road without taxes (s. also following diagrams).

Diagram 5: Average Roundwood Prices, 1994



In cost calculation for forestry there are a lot of fixed and variable elements such as afforestation, conservation, transportation, forest road construction, forest management etc. The analysed countries handle these elements in quite different ways to aggregate them to total production costs. This means that not in all cases all cost elements are included. Most comparable are the costs for harvesting and skidding. That is why the production costs in Diagram 6 include only the costs for these operations (for Switzerland also roundwood transportation costs).

Diagram 6: Average Operation Costs for Roundwood Production, 1994



3.3 Discussion

In this report quantitative data are provided on the yield of European forests expressed as roundwood (fellings o.b.) and the associated cost. This includes stem and branch diameters down to 7 cm. Forests, of course, also a certain amount of smaller branches, roots and litter which adds to the total production of biomass. Under normal conditions these fractions are not extracted from the forests for utilisation. To a certain degree they add to the carbon storage effect but compared to the carbon fixation in the stem this fraction may be considered negligible.

With respect to CO_2 emissions the issue of forest fires is considered important by NABUURS et AL. (1998)[16] In the "FAO Forest Fire Statistics" (1998)[17] the total area affected by fire is classified into forest land, other wooded land, and other land.

[16] The role of European forests in the global carbon cycle – a review, Bimass and bioenergy Vol. 13 No. 6 1997, 1998 published by Elsevier Science Ltd.
[17] Forest Fire Statistics 1995-1997. ECE/TIM/BULL/514, Volume L1, 1998,No. 4

The area of “Forests and other wooded land” (including exploitable and unexploitable forest areas, areas covered by forest roads, fens, small cleared tracts etc.) nearly amounts to 123 Mha (www.aps.fao.org). The level of “Exploitable forests” (areas without legal, economic or technical restrictions on wood production, including areas without any harvesting up to now) was taken from the ETTS V study (Pajuoja, 1995). The area of exploitable forests is much lower than “Forests and other wooded land” and amounts only to 96 Mha.

The above mentioned fire statistics indicates that for the countries covered by this report around 85000 ha forest and other wooded land were affected by fire in 1996 (Table 13). The total forest area incl. other wooded land in the countries concerned amounts to 123 Mill. ha[18]. Thus, the area damaged by fire annually makes up only 0.07 % of 123 Mill. ha which is considered as not significant. On the local scale the costs caused by forest fires may be of importance. On a larger scale, however, they are not significant.

Due to the following reasons the release of CO_2 by forest fires might be much lower than believed or expected by the people.

1. The forest fire, usually, destroys the crown of bigger trees and other plants growing on the ground. The tree bolts, however, which store the major part of CO_2 volume are not burned down by fire.
2. Other wooded land can be densely planted with young trees (e. g. short rotation plantations with species of low density). It can also be sparsely covered by older and bigger trees (e. g. cork oak areas in Portugal and Spain). In both cases the absolute amount of CO_2 released by burning might be less than assumed.
3. Special attention should be paid to the forest or other wooded land of multiple functions such as agroforestry activities. In those cases fire (controlled or uncontrolled) is mainly related to the non forestry activities such as agriculture or cattle-breeding.

[18] Forestworld 1996, Internet 1998

Last but not least forest fires are natural events and can hardly be prevented. Therefore, they should be considered as constant over time and shall not be included in the MARKAL scenarios.

Table 13: Area of forest and wooded land affected by fire in 1996

Country	**ha**
Denmark	9
Finland	914
France	-
Germany	1381
Greece	19247
Ireland	-
Italy	20324
Luxembourg	1
Netherlands	35
Norway	113
Portugal	28724
Spain	11891
Sweden	2181
Switzerland	233
UK	-
Total	**85053**

Currently there is a controversial discussion going on regarding the effect of increasing CO_2 concentrations on plant growth. It is commonly accepted that the total biomass in European forests is increasing. One of the possible reasons for this increase might be the increasing CO_2 concentration in the atmosphere. The authors of this report did not see any possibility to quantify this effect. Other reasons for the growing stock in European forests may be the air born nitrogen which could be considered as a fertilisation effect. Again, this effect can currently not be quantified[19].

[19] Discussion with Kribitzsch/Institut für Weltforstwirtschaft – BFH, Dez. 1998

According to UN/ECE[20] in all countries included in this report, except Portugal, the volume of annual increment is higher than the annual cut. Meanwhile Portugal is also on the best way to establish at least the balance between growth and fellings. Therefore it can be assumed that a sustainable forest management exist in all European countries included in this investigation.

The methodical approach used to generate the data for the MARKAL data sheets is based on various assumptions on differentiation by regions and over time. For this reason the figures in the MARKAL data sheets should be considered as estimations.

The forest production is characterised by various specific aspects and economic options. This makes the modelling of forestry production processes difficult in comparison with modelling in other sectors of the European economy.

[20] UN/ECE Timber Database. Internet 1998

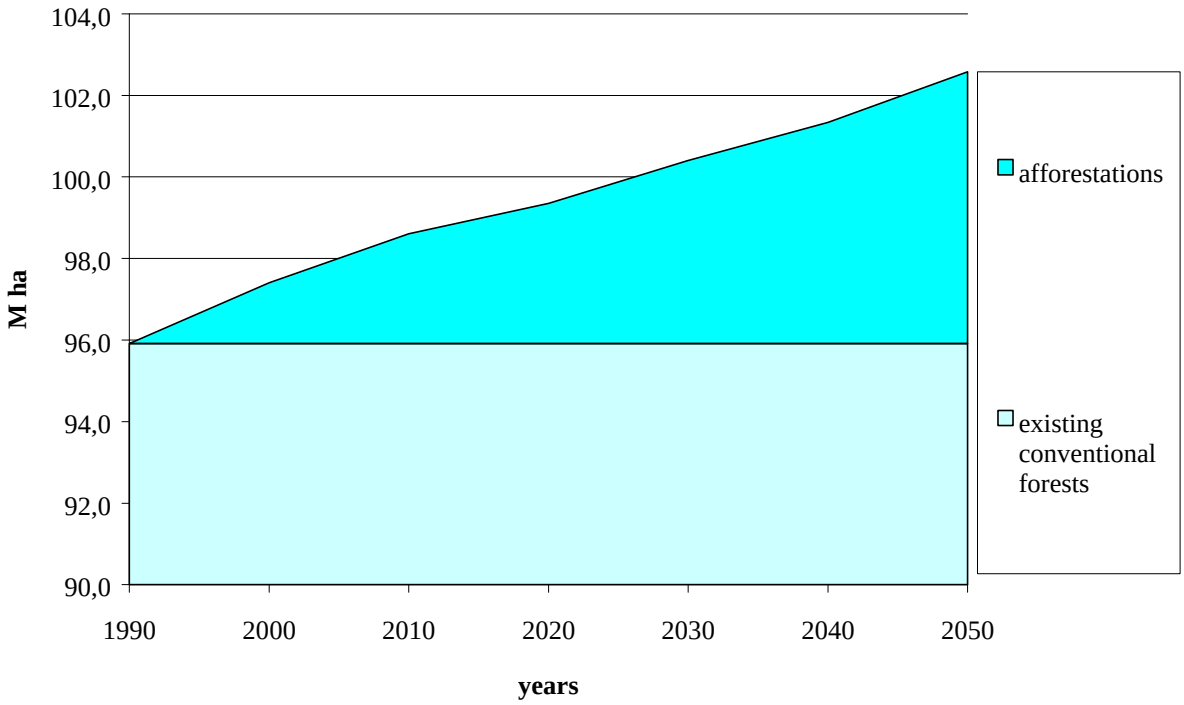
4 Methodical approach for the calculation of MARKAL input data

4.1 ETTS V study as a data base for data on conventional forestry

The main data source for the calculation of the data input in MARKAL data sheets was the ETTS V study giving an outlook on the development of European forests (stock volume, increment) and on the expectable roundwood supply (fellings, removals) up to the year 2040. The study was worked out by forest specialists of the European countries and as an estimation of the ECE-secretariat respectively. The study is based on the present forest structure defined by age classes and tree species. Considering the development of this structure over the period of five decades the possibilities of roundwood utilisation were estimated. Detailed methodical approach is given above.

Before the begin of calculations for the data input in MARKAL data sheets the total forest area [M ha] and the removals [m³ u.b.] given for the regions was differentiated into existing conventional forest and afforestations. The increasing forest area was considered as an upper bound for afforestations, with the consequence that the area of existing conventional forests on the value of 1990 was considered constant over the period 1990 to 2040. The forest area and the removal values for 2050 were calculated based on a non linear extrapolation for the total forest area of each region and for Europe in total. The result for the forest area is given in Diagram 7. The afforestation area in 2050 amounts to 6,5 % of the total area. The growth rate of the forest area is not constant over time.

Diagram 7: Development of forest land use, Europe in total



Source: (ETTS V study)

For the removals there could be two assumptions: In the first approach the increasing area and also the resulting removals could be considered as conventional forests with a rotation period of more then 60-80 years.

For the “Middle” region the following thinning model was assumed:

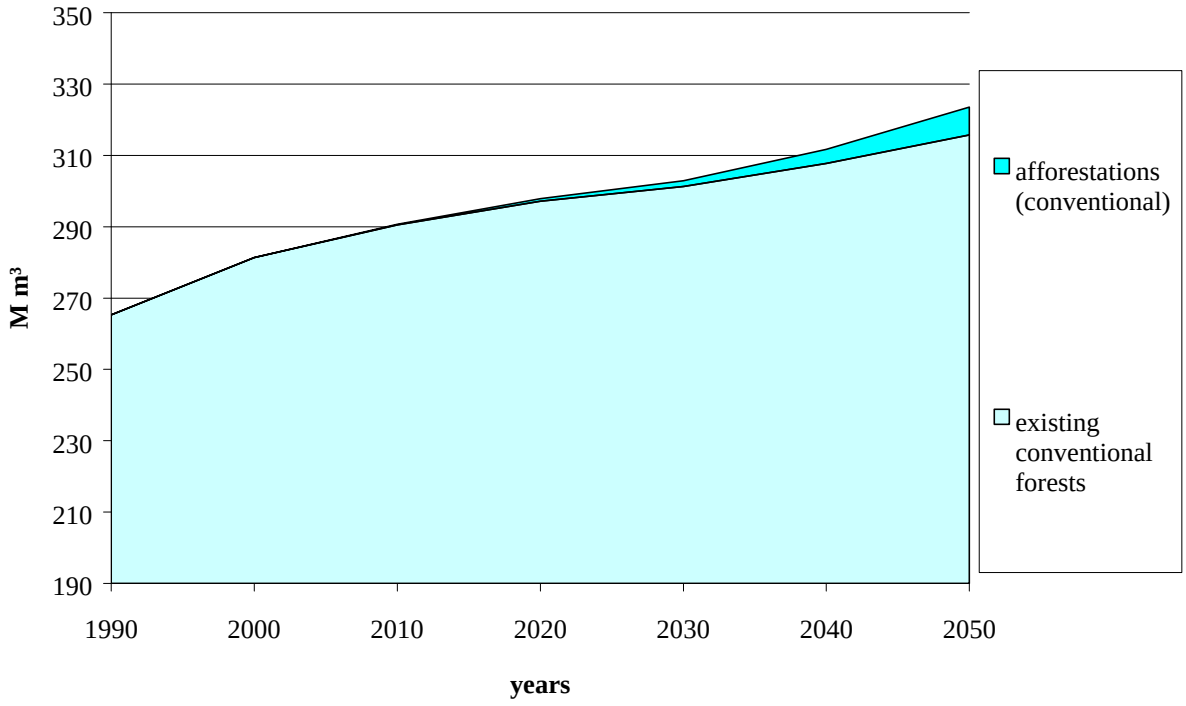
Table 14: Thinnings in a 5-years period [m³ o. b. / ha]

Tree species group	Age	10	20	30	40	50
Coniferous	0	1	3	4	13	18
Non coniferous	0	1	3	5	19	21

For the “South” and “North” region this model was adapted based on removal level for the whole area.

Because of the slow increase of the growing stock volume in the stands and the low thinning possibilities the removals from the afforestation areas amounts only to 2,4 % of the total removals calculated for the year 2050.

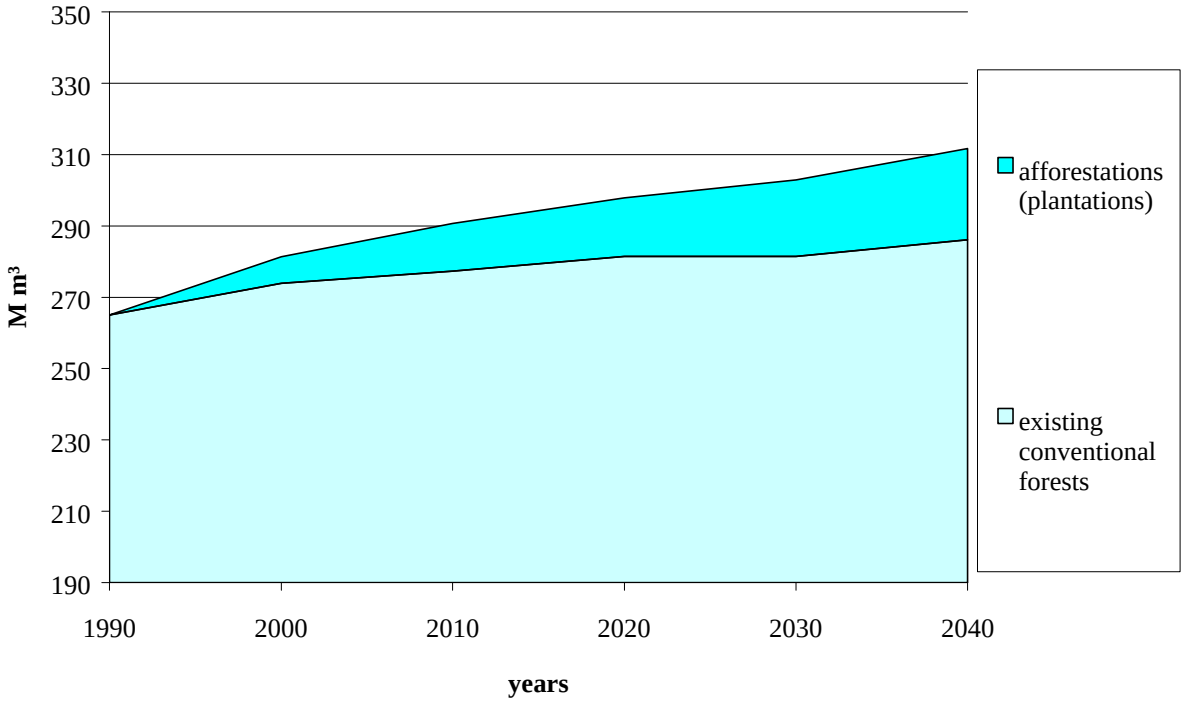
Diagram 8: Development of removals (increasing area as conventional forests), Europe in total



Source: (ETTS V study)

In the second approach the removals from afforested areas are considered as output of plantations with short rotation tree species (for example willow or poplar) and a production period of 3-5 years. The fast increase of the removals is due to the increasing area for afforestations. For the year 2050 such an approach leads to a value of 32 M m³ removals from afforestation or 9,8 % of the total removals respectively.

Diagram 9: Development of removals (increasing area as plantations), Europe in total



Source: (ETTS V study)

4.2 Literature sources as a base for data on short rotation plantations

VAN DER MEIDEN (1987) wrote about the production of renewable resources on former agricultural lands from the pulp production point of view. He investigated the productivity of 6-years poplar hybrids “Rap” and “Dorskamp” in the Netherlands. The removals amount to 6.1 – 6.3 Todm/ha*yr.

Afforestations with fast growing non-coniferous tree species for energy and pulp production within a rotation period of 5 years were studied by DIMITRI (1985). He explains that the productivity of the poplar hybrid “Muhle-Larsen” on forest stand conditions could be on the level of about 5.6 - 8.3 Todm/ha*yr. Only on high productive agricultural lands the output amounts to 11.1 Todm/ha*yr.

HOFMANN (1995) refers to the productivity of poplar hybrid at the level of 5.0 - 22.4 Todm/ha*yr depending on different hybrids and 6.5 - 13.6 Todm/ha*yr for willow hybrids respectively. He expects an increase of yield in wood plantations by applying new scientific methods such as gene cultivation. The application of those methods,

however, require time and patience. For example, more than 20 years time is needed for only one hybrid. A recent study about short rotation wood plantations is worked out in the Research Institute for Short Rotation Tree Species in Hann. Münden, Germany. This study refers to a level of productivity from 10 - 15 Todm/ha*yr. There are examples for a 3- and a 10-years rotation poplar plantation with a yield level of 8 - 10 Todm/ha*yr. In the researched plots production cost amounts from 18 - 22 ECU/Todm.

Recent publications on short rotation plantations give a more realistic picture. REHFUESS (1997) explains about the yield in poplar plantation. He shows that the expected yield are not achieved mainly by lack of rainfall. For the same hybrid “Muhle Larsen” he gives a yield 6,5 – 13 Todm/ha*yr.

A recent study about growing conditions in 5-years rotation plantations carried out by JUG (1997) shows that poplar yield increased in researched plots three to four times in comparison with the yield level in the first rotation.

WIPPERMANN (1993) has conducted his studies on the base of 10 up to 15 Todm/ha*yr wood production. Furthermore he explained that the prices are at a level of 1/3 up to ½ of the cost.

KRAPFENBAUER (1988) expects a decreasing yield after 4-6 rotations, while DREINER et al. (1994) show that based on the high fix cost for preparing the plantation the revenue will be positive only after the third rotation, considering realistic proceeds from wood selling at a level of 40 ECU/Todm.

For compensation of losses in the first years after plantation DIMITRI (1989) recommends subsidies. He warns of a fast boosting of short rotation plantations without a clear perspective under normal market conditions.

HARTMANN and THUNEKE (1997) show the high cost in harvesting wood from short rotation plantations at a level of 20 - 45 ECU/Todm depending on technology of harvesting and time for using harvesters. He shows that the low level of 20 ECU/Todm is not realistic.

THOROE (1993) shows that the short rotation plantation of poplar has a negative economic result (difference between income and total cost) in comparison with conventional fossil based fuels.

Useful economic information about short rotation plantations for energy wood is given by JAKOBS (1993/1994). After a deep analysis of literature resources he reports about the ranges of cost data:

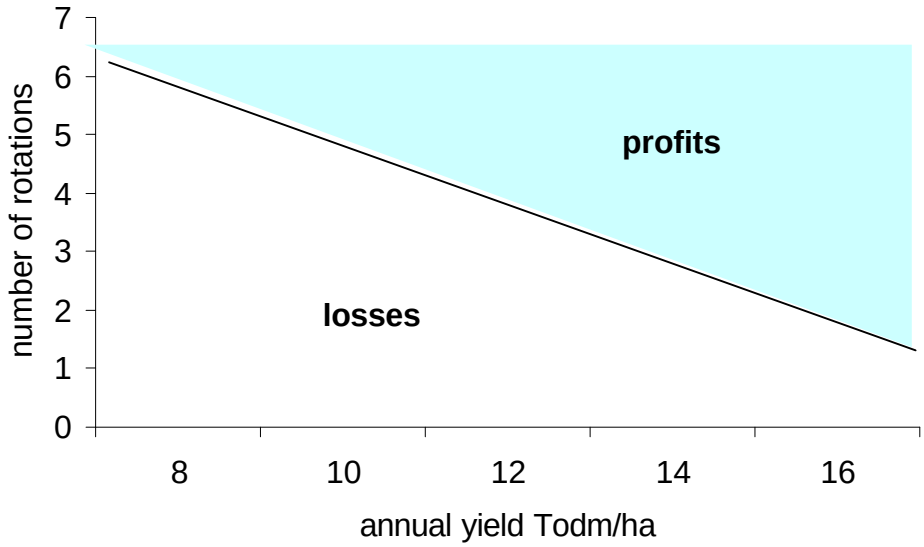
Table 15: Economic data for short rotation plantations (based on JAKOBS)

Parameter	**Unit**	**Lower value**	**upper value**
Annual yield	[Todm/ha*yr]	5	30
Rotation	[yr]	2	15
Yield in one rotation	[Todm/ha*rotation]	10	450
Planting material	[number/ha]	10,000	20,000
Cost for planting material	[ECU/ha*rotation]	650	5,000
Soil preparing, protection, fertilising	[ECU/ha*rotation]	3,615	5,700
Planting	[ECU/ha*rotation]	1,110	1,200
Protection	[ECU/ha*rotation]	0	1,645
Harvesting,	[ECU/ha*rotation]	200	45,000
Transportation	[ECU/ha*rotation]	175	7,900

Different technologies of afforestions in the Northern part of Germany were carried out by FRIEDRICH (1995). The alternatives were discussed from the productivity point of view without mercantile considerations. DÖHRER (1995) gives an estimation on cost for harvesting in wood plantations: 12 –15 ECU/Todm.

Based on the results of KÜPPERS et al. (1997) the following diagram shows the profit-loss-border in dependence of the number of rotations and on the annual yield. Based on expected annual yield at a level of 10 Todm/ha there is a need for more then 4 rotations to get a positive economic result.

Diagram 10: Profit-Losses-Border for short rotation plantations by the number of rotations and the annual yield



assumed proceeds = 50 ECU/Todm

BREMER and THOROE (1989) give a critical revue on the willingness of land owners for afforestation of former agricultural lands. Legal restrictions on re-changes of land use by clear cuttings of wood stands and the decrease of subsidies reduce the willingness for afforestations.

DIEDERICHS (1990) gives a critical analysis of expectations for a high level of yield in wood plantations. He estimates the average productivity in short rotation plantations at the level of 6-7 Todm/ha*yr. He warns in his study against general calculations based on scientific results from small plots and shows that the yield level in reality is often much lower than in theoretical model calculations.

Short rotation, even-aged, monoculture, intensively managed bio-energy plantations, which offer the great environmental advantages of providing a renewable energy source and substituting fossil fuels, are increasingly in contradiction to the environmental demands: natural succession, long rotation, uneven-aged, partially harvested. KIMMINS (1997) concludes that combined biological and technological approaches, which conserve soil organic matter and nutrients, and which utilise organic wastes will have the greatest chance for achieving sustainability.

VAN DER MEIDEN (1987) prefers conventional forests for the increase of forest areas and concludes that “short rotation plantations are not relevant ... in the North of the EU”.

4.3 Explanations on the calculations for MARKAL data sheet

The above literature review is based on publications dealing with management in forestry and forest policy in Europe.

Most of the literature sources on wood plantations in Europe refer to results obtained from small (0,1 - 5 ha) research plots under special natural, legal and economic conditions. The productivity measured 5-10 years after planting was regarded as very high in comparison with conventional forests (up to ten times higher). There are publications on the yields from eucalyptus plantations in the South Region (Portugal) which refer to yields of 30-40 Todm/ha*yr and more. At the same time some authors are convinced, that there are possibilities to increase the yield by better management, fertilising and cultivation of new hybrids of tree species. Recent publications refer to a more conservative yield level of 6,5 – 10 Todm/ha*yr.

Only a few authors give yield figures over a longer period after afforestation. It is to expect that the yield in short rotation plantation without fertilising will decrease over rotations. For stabilising yield the application of fertilisers of about 30-40 kg/ha*yr was considered necessary.

There is no statistic information available about economic results under real market conditions. Global environmental policy decisions have to consider the risk in transforming results obtained on small research plots to a huge area over a long period.

For this reason two different scenarios (conservative and optimistic) were formulated and transformed into MARKAL data sheets (see ANNEX 4). The conservative scenario is characterised by low level of risk for realisation. It is based on an average yield level of about 3.7 - 6 Todm/ha*yr. The optimistic scenario assumes a high yield of 12 – 20 Todm/ha*yr.

*Table 16: Yield in forestry and short rotation plantations, non coniferous, [Todm/ha*a]*

	North	Middle	South
Long rotation forestry (ETTS V, 1990, roundwood with a diameter above 7 cm)	**1.3**	**1.5**	**0.9**
Increment in long rotation forestry (ETTS V, 1990, roundwood with a diameter above 7 cm)	2.7	2.4	1.3
Short rotation plantations, conservative scenario (above ground bio-mass)	**5.0**	**6.0**	**3.7**
Short rotation plantations, optimistic scenario (above ground bio-mass)	**12.0**	**20.0**	**17.5**

It is necessary to underline that the optimistic scenario is applicable only to a small part of land where high soil quality and optimal climatic and economic conditions do exist. For this reason in the MARKAL data sheets the upper bound for the available area in the optimistic scenario was fixed to 15 % of total area available for afforestation taken from ETTS V study.

In addition it has to be considered that bio-mass from short rotation plantations can be used only for energy and as feed stock for chemical processes, whereas yield from conventional forest can also be used for value added applications.

Based on this approach the MARKAL data sheets were structured into the following categories:

- conventional forests (forest area is constant over time at the level of 1990)

  The calculation of removals was carried out based on the first above assumption: afforestations were considered as conventional forests.

- afforestations (increasing forest area)

  There were worked out two kinds of sheets:

  - conventional forests (long rotation period)
  - short rotation plantations (non coniferous tree species such as willow, poplar or eucalyptus)

- conservative scenario,
- optimistic scenario, characterised by a high efficiency of land, man power and energy use.

Further more MARKAL data sheets were structured into regions (north, middle, south) and tree species groups (non coniferous, coniferous).

The total conventional forests have to be considered as a group of areas with different age classes. This is important because the factor input in forest production mostly depends on the age of different stands. That is why the average data (land, cost and so on) for each period is a conglomerate of the specific data for stands in different age classes.

I N P U T

Land [ha/Todm]

Input of yearly necessary land divided by the production of roundwood (removals)

Source: ETTS V study

Energy [MJ/Todm]

Input of energy for the production of roundwood (reforestation and afforestation respectively, conservation, harvesting (thinning, clear cutting), skidding (transport to the forest road). No input of energy for fixed expenses (administration etc.).

Source: literature

Labour [man-hours/Todm]

Input of labour for the production of roundwood (reforestation and afforestation respectively, conservation, weeding, thinning, clear cutting, skidding to the forest road). No input of labour for administration etc.

Source: statistic information, literature

All physical input parameters (land, energy and labour) are only given as a basis for information. Land, labour and energy cost are already included in the cost positions mentioned below.

O U T P U T

Roundwood [Todm]

Roundwood production based on the removals in m³ u.b.

Residuals [Todm/Todm]

Bark and harvesting residues not used up to now, calculated as the difference between the “Fellings in m³ o.b.” and the “Removals in m³ u.b.” (see the ETTS V study).

Source: the ETTS V study

Investment [ECU1995/Todm]

In case of conventional forestry the parameter investment contains only the costs for machinery and technical equipment.

In case of short rotation plantations this parameter investment contains also the costs for site preparation, planting including the plant material.

All kinds of costs included. No direct subsidies and taxes were considered.

Source: inquiry (see above), statistic information, literature

Fixed costs [ECU1995/Todm]

Annual costs for forest protection (incl. hunting), forest road construction, recreation, administration and others. All kinds of costs included. No direct subsidies and taxes were considered.

Source: inquiry (see above), statistic information, literature

Variable costs [ECU1995/Todm]

(roundwood) This parameter includes annual operation cost for harvesting (thinning and clear cutting) and skidding. All kinds of costs included. No direct subsidies and taxes were considered.

(reforestation/afforestation) This parameter includes annual operation costs for reforestation/afforestation, replanting, conservation. All kinds of costs included. No direct subsidies and taxes were considered.

Source: inquiry (see above), statistic information, literature

Life for investment [years]

This parameter characterise the period of using the investments. It could be used as a base for deprecations.

Source: statistic information, literature

Bounds [kha]

Because of the influence of the age class structure over time the bounds for conventional forests have to be considered strictly. They could be modified in MARKAL only in equal percentage over time.

For plantations (conservative scenario) the bounds were set equal to the area available for afforestation. For the optimistic scenario the bound was set equal to 15 % of the available area for afforestation.

The plantation area can be changed over time.

Source: ETTS V study

Lower heating value [GJ/Todm]

Source: literature

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Annex

Annex 1: FAO-Statistics on current roundwood production and use

Table 1: Production, import, export and consumption of roundwood in 1994 [1000 m³]

Country	Production	Imports	Exports	Consumption
Norway	8744	3414	540	11618
Sweden	56500	7524	1271	62753
Finland	47928	7563	1700	53791
Denmark	2282	604	389	2497
Subtotal North Europe	115454	19105	3900	130659
UK	8155	595	59	8691
Ireland	2008	76	424	1660
Netherlands	1072	852	841	1083
Belgium-Luxembourg	4340	4087	1690	6737
Germany	37012	2633	7121	32524
France	42850	2917	3272	42495
Switzerland	4974	1144	1238	4880
Austria	14960	8146	2179	20927
Subtotal Middle Europe	115371	20450	16824	118997
Spain	13815	1354	283	14886
Portugal	9819	1113	714	10218
Italy	9465	7519	15	16969
Greece	2779	39	59	2759
Subtotal South	35878	10025	1071	44832
Total Europe	266703	49580	21795	294488

Annex 2: FAO-Statistics on current roundwood production and use

Table 2: Production, import, export and consumption of sawlogs and veneerlogs in 1994 [1000 m³]

Country	Production	Imports	Exports	Consumption
Norway	4293	-	-	-
Sweden	28900	-	-	-
Finland	22481	-	-	-
Denmark	875	-	-	-
Subtotal North Europe	56549	-	-	-
UK	3915	-	-	-
Ireland	1337	-	-	-
Netherlands	457	-	-	-
Belgium-Luxembourg	2720	-	-	-
Germany	21073	-	-	-
France	21795	-	-	-
Switzerland	3234	-	-	-
Austria	8549	-	-	-
Subtotal Middle Europe	63080	-	-	-
Spain	5981	-	-	-
Portugal	4211	-	-	-
Italy	2180	-	-	-
Greece	650	-	-	-
Subtotal South	13022	-	-	-
Total Europe	132651	-	-	-

Annex 3: FAO-Statistics on current roundwood production and use

Table 3: Production, import, export and consumption of pulpwood and particles in 1994 [1000 m³]

Country	Production	Imports	Exports	Consumption
Norway	3771	-	-	-
Sweden	23300	-	-	-
Finland	21021	-	-	-
Denmark	571	-	-	-
Subtotal North Europe	48663	-	-	-
UK	4000	-	-	-
Ireland	611	-	-	-
Netherlands	306	-	-	-
Belgium-Luxembourg	860	-	-	-
Germany	10744	-	-	-
France	10615	-	-	-
Switzerland	517	-	-	-
Austria	2552	-	-	-
Subtotal Middle Europe	30205	-	-	-
Spain	4761	-	-	-
Portugal	4928	-	-	-
Italy	820	-	-	-
Greece	410	-	-	-
Subtotal South	10919	-	-	-
Total Europe	89787	-	-	-

Annex 4: FAO-Statistics on current roundwood production and use

Table 4: Production, import, export and consumption of fuelwood and charcoal in 1994 [1000 m³]

Country	Production	Imports	Exports	Consumption
Norway	470	344	1	813
Sweden	3800	95	14	3881
Finland	4101	45	1	4145
Denmark	485	80	5	560
Subtotal North Europe	8856	564	21	9399
UK	230	202	6	426
Ireland	60	1	2	59
Netherlands	204	90	50	244
Belgium-Luxembourg	550	136	66	620
Germany	3795	460	74	4181
France	9800	127	443	9484
Switzerland	1153	64	51	1166
Austria	3259	295	6	3548
Subtotal Middle Europe	19051	1375	698	19728
Spain	2338	122	97	2363
Portugal	500	7	20	487
Italy	5481	363	3	5841
Greece	1519	12	1	1530
Subtotal South	9838	504	121	10221
Total Europe	37745	2443	840	39348

Annex 5: FAO-Statistics on current roundwood production and use

Table 5: Production, import, export and consumption of other industrial roundwood in 1994 [1000 m³]

Country	Production	Imports	Exports	Consumption
Norway	210	-	-	-
Sweden	500	-	-	-
Finland	325	-	-	-
Denmark	351	-	-	-
Subtotal North Europe	1386	-	-	-
UK	10	-	-	-
Ireland	0	-	-	-
Netherlands	105	-	-	-
Belgium-Luxembourg	210	-	-	-
Germany	1400	-	-	-
France	640	-	-	-
Switzerland	70	-	-	-
Austria	600	-	-	-
Subtotal Middle Europe	3035	-	-	-
Spain	735	-	-	-
Portugal	180	-	-	-
Italy	984	-	-	-
Greece	200	-	-	-
Subtotal South	2099	-	-	-
Total Europe	6520	-	-	-

Annex 6: FAO-Statistics on current roundwood production and use

Table 6: Production, import, export and consumption of sawnwood and sleepers in 1994 [1000 m³]

Country	Production	Imports	Exports	Consumption
Norway	2415	778	778	2415
Sweden	13816	243	10659	3400
Finland	9780	216	7209	2787
Denmark	583	2326	100	2809
Subtotal North Europe	26594	3563	18746	11411
UK	2225	8687	93	10819
Ireland	709	405	248	866
Netherlands	383	3745	411	3717
Belgium-Luxembourg	1209	1886	635	2460
Germany	13567	5769	1807	17529
France	10176	2064	1065	11175
Switzerland	1320	551	150	1721
Austria	7429	990	4557	3862
Subtotal Middle Europe	37018	24097	8966	52149
Spain	2717	1560	64	4213
Portugal	1670	130	568	1232
Italy	1808	6566	109	8265
Greece	337	395	8	724
Subtotal South	6532	8651	749	14434
Total Europe	70144	36311	28461	77994

Annex 7: FAO-Statistics on current roundwood production and use

Table 7: Production, import, export and consumption of veneer sheets in 1994[1000 m³]

Country	Production	Imports	Exports	Consumption
Norway	0	17	3	14
Sweden	13	31	11	33
Finland	50	6	68	-12
Denmark	14	18	8	24
Subtotal North Europe	77	72	90	59
UK	0	87	11	76
Ireland	0	5	0	5
Netherlands	23	29	17	35
Belgium-Luxembourg	45	37	25	57
Germany	380	194	143	431
France	58	88	58	88
Switzerland	30	5	8	27
Austria	27	17	11	33
Subtotal Middle Europe	563	462	273	752
Spain	119	36	27	128
Portugal	110	6	3	113
Italy	500	139	23	616
Greece	8	3	1	10
Subtotal South	737	184	54	867
Total Europe	1377	718	417	1678

Annex 8: FAO-Statistics on current roundwood production and use

Table 8: Production, import, export and consumption of plywood in 1994 [1000 m³]

Country	Production	Imports	Exports	Consumption
Norway	4	71	2	73
Sweden	85	126	49	162
Finland	700	18	627	91
Denmark	11	171	37	145
Subtotal North Europe	800	386	715	471
UK	5	1202	23	1184
Ireland	0	75	4	71
Netherlands	15	560	102	473
Belgium-Luxembourg	68	267	134	201
Germany	397	967	131	1233
France	485	304	250	539
Switzerland	3	144	3	144
Austria	150	104	158	96
Subtotal Middle Europe	1123	3623	805	3941
Spain	210	35	67	178
Portugal	27	9	3	33
Italy	427	257	108	576
Greece	70	3	14	59
Subtotal South	734	304	192	846
Total Europe	2657	4313	1712	5258

Annex 9: FAO-Statistics on current roundwood production and use

Table 9: Production, import, export and consumption of particleboard in 1994 [1000 m³]

Country	Production	Imports	Exports	Consumption
Norway	372	48	187	233
Sweden	609	186	140	655
Finland	477	12	200	289
Denmark	328	316	42	602
Subtotal North Europe	1786	562	569	1779
UK	1803	1167	190	2780
Ireland	85	36	31	90
Netherlands	36	755	127	664
Belgium-Luxembourg	2400	195	1872	723
Germany	8639	1687	1316	9010
France	2534	708	913	2329
Switzerland	656	214	427	443
Austria	1666	164	909	921
Subtotal Middle Europe	17819	4926	5785	16960
Spain	1730	328	203	1855
Portugal	757	55	455	357
Italy	2202	346	121	2427
Greece	250	28	16	262
Subtotal South	4939	757	795	4901
Total Europe	24544	6245	7149	23640

Annex 10: FAO-Statistics on current roundwood production and use

Table 10: Production, import, export and consumption of fibreboard in 1994 [1000 m³]

Country	Production	Imports	Exports	Consumption
Norway	194	19	13	200
Sweden	188	101	105	184
Finland	118	46	75	89
Denmark	79	71	39	111
Subtotal North Europe	579	237	232	584
UK	400	341	128	613
Ireland	180	39	115	104
Netherlands	36	249	66	219
Belgium-Luxembourg	48	200	57	191
Germany	854	403	324	933
France	520	109	311	318
Switzerland	108	110	55	163
Austria	118	28	54	92
Subtotal Middle Europe	2264	1479	1110	2633
Spain	550	125	273	402
Portugal	336	44	277	103
Italy	222	229	427	24
Greece	35	94	1	128
Subtotal South	1143	492	978	657
Total Europe	3986	2208	2320	3874

Annex 11: FAO-Statistics on current roundwood production and use

Table 11: Production, import, export and consumption of chemical wood pulp in 1994 [1000 MT]

Country	Production	Imports	Exports	Consumption
Norway	609	89	272	426
Sweden	6989	189	2568	4610
Finland	5844	70	1420	4494
Denmark	0	51	0	51
Subtotal North Europe	13442	399	4260	9581
UK	0	1607	8	1599
Ireland	0	9	0	9
Netherlands	0	803	152	651
Belgium-Luxembourg	168	530	119	579
Germany	698	3552	179	4071
France	1782	2011	446	3347
Switzerland	147	401	88	460
Austria	1042	504	224	1322
Subtotal Middle Europe	3837	9417	1216	12038
Spain	1233	381	688	926
Portugal	1539	70	1059	550
Italy	21	2487	19	2489
Greece	0	80	0	80
Subtotal South	2793	3018	1766	4045
Total Europe	20072	12834	7242	25664

Annex 12: FAO-Statistics on current roundwood production and use

Table 12: Production, import, export and consumption of mechanical wood pulp in 1994 [1000 MT]

Country	Production	Imports	Exports	Consumption
Norway	1516	3	179	1340
Sweden	2858	3	208	2653
Finland	3631	6	0	3637
Denmark	75	8	0	83
Subtotal North Europe	8080	20	387	7713
UK	502	95	13	584
Ireland	0	1	0	1
Netherlands	119	30	2	147
Belgium-Luxembourg	210	21	0	231
Germany	1236	98	8	1326
France	886	47	0	933
Switzerland	133	5	1	137
Austria	399	21	0	420
Subtotal Middle Europe	3485	318	24	3779
Spain	83	3	12	74
Portugal	0	3	3	0
Italy	381	133	13	501
Greece	25	0	0	25
Subtotal South	489	139	28	600
Total Europe	12054	477	439	12092

Annex 13: FAO-Statistics on current roundwood production and use

Table 13: Production, import, export and consumption of other pulp in 1994 [1000 MT]

Country	Production	Imports	Exports	Consumption
Norway	162	0	134	28
Sweden	569	38	61	546
Finland	579	56	74	561
Denmark	71	4	62	13
Subtotal North Europe	1381	98	331	1148
UK	124	206	0	330
Ireland	0	11	0	11
Netherlands	0	62	2	60
Belgium-Luxembourg	0	15	3	12
Germany	23	243	12	254
France	123	72	26	169
Switzerland	0	7	0	7
Austria	193	34	11	216
Subtotal Middle Europe	463	650	54	1059
Spain	141	35	17	159
Portugal	0	1	0	1
Italy	54	152	0	206
Greece	0	9	0	9
Subtotal South	195	197	17	375
Total Europe	**2039**	**945**	**402**	**2582**

Annex 14: FAO-Statistics on current roundwood production and use

Table 14: Production, import, export and consumption of recovered paper in 1994 [1000 MT]

Country	Production	Imports	Exports	Consumption
Norway	178	60	149	89
Sweden	920	583	166	1337
Finland	472	123	34	561
Denmark	466	171	308	329
Subtotal North Europe	2036	937	657	2316
UK	3675	174	419	3430
Ireland	170	10	31	149
Netherlands	2202	1079	1099	2182
Belgium-Luxembourg	686	96	644	138
Germany	9690	719	2248	8161
France	2970	1226	659	3537
Switzerland	754	185	262	677
Austria	902	364	63	1203
Subtotal Middle Europe	21049	3853	5425	19477
Spain	1736	635	32	2339
Portugal	270	21	39	252
Italy	3310	1069	39	4340
Greece	175	6	21	160
Subtotal South	5491	1731	131	7091
Total Europe	28576	6521	6213	28884

Annex 15: FAO-Statistics on current roundwood production and use

Table 15: Production, import, export and consumption of printing and writing paper in 1994. [1000 MT]

Country	Production	Imports	Exports	Consumption
Norway	606	156	596	166
Sweden	2060	131	1798	393
Finland	6159	31	5554	636
Denmark	93	133	76	150
Subtotal North Europe	8918	451	8024	1345
UK	1819	2653	672	3800
Ireland	0	130	7	123
Netherlands	902	759	743	918
Belgium-Luxembourg	610	1084	849	845
Germany	5865	3218	2947	6136
France	3268	2095	1592	3771
Switzerland	381	397	256	522
Austria	1728	339	1965	102
Subtotal Middle Europe	14573	10675	9031	16217
Spain	874	1010	332	1552
Portugal	435	121	292	264
Italy	2595	1224	812	3007
Greece	125	157	1	281
Subtotal South	4029	2512	1437	5104
Total Europe	27520	13638	18492	22666

Annex 16: FAO-Statistics on current roundwood production and use

Table 16: Production, import, export and consumption of paper and other paperboard in 1994 [1000 MT]

Country	Production	Imports	Exports	Consumption
Norway	40	1	0	41
Sweden	155	2	0	157
Finland	211	41	269	-17
Denmark	0	340	58	282
Subtotal North Europe	406	384	327	463
UK	315	43	38	320
Ireland	0	181	28	153
Netherlands	0	1139	1188	-49
Belgium-Luxembourg	36	410	152	294
Germany	954	90	97	947
France	376	155	217	314
Switzerland	0	182	183	-1
Austria	46	6	1	51
Subtotal Middle Europe	1727	2206	1904	2029
Spain	252	227	100	379
Portugal	9	149	66	92
Italy	325	87	73	339
Greece	44	135	0	179
Subtotal South	630	598	239	989
Total Europe	2763	3188	2470	3481

Annex 17: FAO-Statistics on current roundwood production and use

Table 17: Production, import, export and consumption of household and sanitary paper in 1994 [1000 MT]

Country	Production	Imports	Exports	Consumption
Norway	29	0	13	16
Sweden	295	4	82	217
Finland	188	5	105	88
Denmark	0	57	14	43
Subtotal North Europe	512	66	214	364
UK	551	164	25	690
Ireland	0	0	0	0
Netherlands	167	30	20	177
Belgium-Luxembourg	118	60	98	80
Germany	864	292	212	944
France	408	152	66	494
Switzerland	154	86	46	194
Austria	96	17	24	89
Subtotal Middle Europe	2358	801	491	2668
Spain	293	68	26	335
Portugal	61	4	11	54
Italy	510	28	200	338
Greece	247	1	6	242
Subtotal South	1111	101	243	969
Total Europe	3981	968	948	4001

Annex 18: FAO-Statistics on current roundwood production and use

Table 18: Production, import, export and consumption of wrapping and packaging paper, board in 1994 [1000 MT]

Country	Production	Imports	Exports	Consumption
Norway	466	180	389	257
Sweden	4358	265	3883	740
Finland	2906	118	2322	702
Denmark	252	53	75	230
Subtotal North Europe	7982	616	6669	1929
UK	2375	1877	317	3935
Ireland	36	0	0	36
Netherlands	1631	6	26	1611
Belgium-Luxembourg	202	504	80	626
Germany	5275	2700	1884	6091
France	3585	1592	1011	4166
Switzerland	509	286	370	425
Austria	1330	271	669	932
Subtotal Middle Europe	14943	7236	4357	17822
Spain	1985	688	313	2360
Portugal	444	111	234	321
Italy	3120	1685	550	4255
Greece	325	52	14	363
Subtotal South	5874	2536	1111	7299
Total Europe	28799	10388	12137	27050

Annex 19: FAO-Statistics on current roundwood production and use

Table 19: Production, import, export and consumption of newsprint in 1994 [1000 MT]

Country	Production	Imports	Exports	Consumption
Norway	1007	20	771	256
Sweden	2415	39	2030	424
Finland	1446	17	1253	210
Denmark	0	238	1	237
Subtotal North Europe	4868	314	4055	1127
UK	769	1696	202	2263
Ireland	0	71	2	69
Netherlands	311	432	227	516
Belgium-Luxembourg	122	193	97	218
Germany	1499	1293	575	2217
France	844	488	525	807
Switzerland	288	116	68	336
Austria	403	69	6	466
Subtotal Middle Europe	4236	4358	1702	6892
Spain	99	380	14	465
Portugal	0	62	0	62
Italy	154	471	4	621
Greece	9	60	0	69
Subtotal South	262	973	18	1217
Total Europe	9366	5645	5775	9236

Annex 20: Production, average Prices and Production Costs

Table 1: Production, average Prices and Production Costs, 1994, Finland

Structure of Roundwood	Production		Average Prices		Average Production Costs	
	[M m³]	[M Todm]	[NC/m³]	[ECU/Todm]	[NC/m³]	[ECU/Todm]
Sawlogs + Veneer Logs	1.070	717	353	85		
Pulpwood + Particles	3.998	2.679	214	52		
Fuelwood + Charcoal	2.714	1.818				
Other indstr.Roundwood	50	34				
Non Coniferous	**7.832**	**5.247**	**157**	**38**		
Sawlogs + Veneer Logs	21.411	9.956	269	93		
Pulpwood + Particles	17.023	7.916	169	59		
Fuelwood + Charcoal	1.387	645				
Other indstr. Roundwood	275	128				
Coniferous	**40.096**	**18.645**	**215**	**75**		
Sawlogs + Veneer Logs	**22.481**	**10.673**	**273**	**93**		
Pulpwood + Particles	**21.021**	**10.594**	**177**	**57**		
Fuelwood + Charcoal	**4.101**	**2.463**				
Other indstr. Roundwood	**325**	**161**				
Non Coniferous + Coniferous	**47.928**	**23.892**	**206**	**67**		

Notes/Sources:

Production	FAO Yearbook 1994
Average Prices	expert estimation for the whole country, at forest roadside, without taxes;
Average Production Costs	expert estimation for the whole country, including all costs for harvesting, skidding, afforestion, conservation, management, etc.;
m³	m³ u. b.
adw (Absolutly dry weight)	conversion factor: Non Coniferious 670 kg/m³ o. b., Coniferious 465 kg/m³ o. b.; Directives 68/89/ECE; Germany, Jan. 23. 1968
ECU/FIM	quotation 6.19 FIM = 1 ECU; Statistisches Bundesamt

Annex 2: Production, average Prices and Production Costs

Table 2: Production, average Prices and Production Costs, 1994, Denmark

Structure of Roundwood	Production		Average Prices		Average Production Costs	
	[M m³]	[M Todm]	[NC/m³]	[ECU/Todm]	[NC/m³]	[ECU/Todm]
Sawlogs + Veneer Logs	414	277	505	100	80	16
Pulpwood + Particles	50	34				
Fuelwood + Charcoal	274	184	350	69	150	30
Other indstr.Roundwood	26	17	600	119	100	20
Non Coniferous	**764**	**512**	**420**	**83**	**101**	**20**
Sawlogs + Veneer Logs	461	214	265	76	100	29
Pulpwood + Particles	521	242	180	51	160	46
Fuelwood + Charcoal	211	98	260	74	230	66
Other indstr. Roundwood	325	151	200	57	160	46
Coniferous	**1.518**	**706**	**221**	**63**	**152**	**43**
Sawlogs + Veneer Logs	**875**	**492**	**379**	**89**	**91**	**21**
Pulpwood + Particles	**571**	**276**	**164**	**45**	**146**	**40**
Fuelwood + Charcoal	**485**	**282**	**311**	**71**	**185**	**42**
Other indstr. Roundwood	**351**	**169**	**230**	**63**	**156**	**43**
Non Coniferous + Coniferous	**2.282**	**1.218**	**288**	**71**	**134**	**33**

Notes/Sources:

Production	FAO Yearbook 1994
Average Prices	expert estimation for the whole country, at forest roadside, without taxes;
Average Production Costs	expert estimation for the whole country, including all costs for harvesting, skidding, afforestion, conservation, management, etc.;
m³	m³ u. b.
adw (Absolutly dry weight)	conversion factor: Non Coniferious 670 kg/m³ o. b., Coniferious 465 kg/m³ o. b.; Directives 68/89/ECE; Germany, Jan. 23. 1968
ECU/DKR	quotation 7.54 DKR = 1 ECU; Statistisches Bundesamt

Annex 2: Production, average Prices and Production Costs

Table 3: Production, average Prices and Production Costs, 1994, Germany

Structure of Roundwood	Production		Average Prices		Average Production Costs	
	[M m³]	[M Todm]	[NC/m³]	[ECU/Todm]	[NC/m³]	[ECU/Todm]
Sawlogs + Veneer Logs	3.064	2.053	206	160	164	127
Pulpwood + Particles	3.577	2.397	43	33	175	136
Fuelwood + Charcoal	2.730	1.829	46	35	199	155
Other indstr.Roundwood	800	536	72	56	214	167
Non Coniferous	**10.171**	**6.815**	**95**	**74**	**181**	**141**
Sawlogs + Veneer Logs	18.009	8.374	99	111	138	155
Pulpwood + Particles	7.167	3.333	36	40	165	185
Fuelwood + Charcoal	1.065	495	21	23	163	182
Other indstr. Roundwood	600	279	70	78	167	187
Coniferous	**26.841**	**12.481**	**79**	**88**	**147**	**165**
Sawlogs + Veneer Logs	**21.073**	**10.427**	**115**	**121**	**142**	**149**
Pulpwood + Particles	**10.744**	**5.729**	**38**	**37**	**168**	**164**
Fuelwood + Charcoal	**3.795**	**2.324**	**39**	**33**	**189**	**161**
Other indstr. Roundwood	**1.400**	**815**	**71**	**63**	**194**	**174**
Non Coniferous + Coniferous	**37.012**	**19.296**	**83**	**83**	**156**	**156**

Notes/Sources:

Production	FAO Yearbook 1994
Average Prices	expert estimation for the whole country, at forest roadside, without taxes;
Average Production Costs	expert estimation for the whole country, including all costs for harvesting, skidding, afforestion, conservation, management, etc.;
m³	m³ u. b.
adw (Absolutly dry weight)	conversion factor: Non Coniferious 670 kg/m³ o. b., Coniferious 465 kg/m³ o. b.; Directives 68/89/ECE; Germany, Jan. 23. 1968
ECU/DM	quotation 1.92 DM = 1 ECU; Statistisches Bundesamt

Annex 2: Production, average Prices and Production Costs

Table 4: Production, average Prices and Production Costs, 1994, UK

Structure of Roundwood	Production		Average Prices		Average Production Costs	
	[M m³]	[M Todm]	[NC/m³]	[ECU/Todm]	[NC/m³]	[ECU/Todm]
Sawlogs + Veneer Logs	420	281	50	96	10	19
Pulpwood + Particles	300	201	15	29	12	23
Fuelwood + Charcoal	130	87	15	29	12	23
Other indstr.Roundwood	0	0				
Non Coniferous	**850**	**570**	**32**	**62**	**11**	**21**
Sawlogs + Veneer Logs	3.495	1.625	40	110	10	28
Pulpwood + Particles	3.700	1.721	22	61	15	41
Fuelwood + Charcoal	100	47	10	28	10	28
Other indstr. Roundwood	10	5	22	61	15	41
Coniferous	**7.305**	**3.397**	**30**	**84**	**13**	**35**
Sawlogs + Veneer Logs	**3.915**	**1.907**	**41**	**108**	**10**	**26**
Pulpwood + Particles	**4.000**	**1.922**	**21**	**57**	**15**	**39**
Fuelwood + Charcoal	**230**	**134**	**13**	**28**	**11**	**25**
Other indstr. Roundwood	**10**	**5**	**22**	**61**	**15**	**41**
Non Coniferous + Coniferous	**8.155**	**3.966**	**31**	**81**	**12**	**33**

Notes/Sources:

Production	FAO Yearbook 1994
Average Prices	expert estimation for the whole country, at forest roadside, without taxes;
Average Production Costs	expert estimation for the whole country, including all costs for harvesting, skidding, afforestion, conservation, management, etc.;
m³	m³ u. b.
adw (Absolutly dry weight)	conversion factor: Non Coniferious 670 kg/m³ o. b., Coniferious 465 kg/m³ o. b.; Directives 68/89/ECE; Germany, Jan. 23. 1968
ECU/Pfund Sterling	quotation 0.78 Pfund Sterling = 1 ECU; Statistisches Bundesamt

Annex 2: Production, average Prices and Production Costs

Table 5: Production, average Prices and Production Costs, 1994, Switzerland

Structure of Roundwood	Production		Average Prices		Average Production Costs	
	[M m³]	[M Todm]	[NC/m³]	[ECU/Todm]	[NC/m³]	[ECU/Todm]
Sawlogs + Veneer Logs	432	289	156	148	76	72
Pulpwood + Particles	165	111	56	53	76	72
Fuelwood + Charcoal	858	575	97	92	76	72
Other indstr.Roundwood	10	7			76	72
Non Coniferous	**1.465**	**982**	**109**	**104**	**76**	**72**
Sawlogs + Veneer Logs	2.802	1.303	128	175	76	104
Pulpwood + Particles	352	164	76	104	76	104
Fuelwood + Charcoal	295	137	60	82	76	104
Other indstr. Roundwood	60	28		0	76	104
Coniferous	**3.509**	**1.632**	**115**	**157**	**76**	**104**
Sawlogs + Veneer Logs	**3.234**	**1.592**	**132**	**170**	**76**	**98**
Pulpwood + Particles	**517**	**274**	**70**	**84**	**76**	**91**
Fuelwood + Charcoal	**1.153**	**712**	**88**	**90**	**76**	**78**
Other indstr. Roundwood	**70**	**35**			**76**	**98**
Non Coniferous + Coniferous	**4.974**	**2.613**	**113**	**137**	**76**	**92**

Notes/Sources:

Production	FAO Yearbook 1994
Average Prices	expert estimation for the whole country, at forest roadside, without taxes;
Average Production Costs	expert estimation for the whole country,. including all costs for harvesting, skidding, afforestion, conservation, management, etc.;
m³	m³ u. b.
adw (Absolutly dry weight)	conversion factor: Non Coniferious 670 kg/m³ o. b., Coniferious 465 kg/m³ o. b.; Directives 68/89/ECE; Germany, Jan. 23. 1968
ECU/CHF	quotation 1.57 CHF = 1 ECU;

Annex 2: Production, average Prices and Production Costs

Table 6: Quotation ECU/national Currency, 1994

Country	**Quotation** **1 ECU =**	**National Currency**
Finland	6.19	FIM
Denmark	7.54	DKR
Germany	1.92	DM
UK	0.78	Pound
Switzerland	1.57	CHF
USA	1.18	US $

Annex 2: Production, average Prices and Production Costs

Table 7: Production costs in Forestry of Germany in 1994, all kinds of owner ship

Operation	**DM/m³**	**%**
harvesting	30.52	20.3
skidding	12.64	8.5
afforestation	18.68	10.9
conservation	7.61	4.6
protection	10.23	6.0
forest road construction	9.63	5.9
other operations	4.99	3.5
hunting	2.70	1.7
recreation	3.64	2.1
Administration	51.77	32.8
Equipment	6.03	3.8
Total	**158.45**	**100.0**

ANNEX 21: Outlook for European Forest Resources and Roundwood Supply

	Unit	1990	2000	2010	2020	2030	2040
Exploitable forest:							
Area. total	**Kha**	**95919**	**97407**	**98606**	**99351**	**100405**	**101333**
- coniferous	Kha	64392	65119	65666	66043	66560	66994
- non coniferous	Kha	31527	32288	32940	33308	33845	34339
Growing stock. total	**KTodm o.b.**	**6839261**	**7477128**	**8173048**	**8914971**	**10108502**	**10505144**
- coniferous	KTodm o.b.	4118383	4571993	5061497	5590726	6576240	6771152
- non coniferous	KTodm o.b.	2720877	2905134	3111551	3324245	3532262	3733992
NAI. total	**KTodm o.b.**	**243913**	**257467**	**266414**	**274211**	**259515**	**288267**
- coniferous	KTodm o.b.	153548	162954	170179	177445	161977	189649
- non coniferous	KTodm o.b.	90365	94513	96235	96765	97538	98618
Fellings. total	**KTodm o.b.**	**175625**	**184759**	**190239**	**194396**	**197718**	**202502**
- coniferous	KTodm o.b.	106177	111948	116349	119484	121193	124715
- non coniferous	KTodm o.b.	69448	72811	73890	74913	76525	77786
Removals. total	**KTodm u.b.**	**140130**	**148612**	**153243**	**156893**	**159866**	**164067**
- coniferous	KTodm u.b.	85296	90502	94121	96817	98357	101469
- non coniferous	KTodm u.b.	54833	58110	59122	60076	61509	62598
Other wooded land							
- Area unexploitable	Kha	9526	9535	9542	9550	9559	9567
- Area OWL	Kha	13373	13386	13395	13404	13414	13424
Removals. not exploit.	**KTodm u.b.**	**6641**	**6865**	**7026**	**7190**	**7358**	**7532**
- coniferous	KTodm u.b.	1809	1879	1931	1984	2036	2093
- non coniferous	KTodm u.b.	4832	4986	5095	5207	5322	5440
Total							
- coniferous. logs	KTodm u.b.	40219	51508	53719	55288	56345	57604
- coniferous. other	KTodm u.b.	39894	42375	43769	44821	45384	47162
- non coniferous. logs	KTodm u.b.	15232	17082	17174	17833	18140	18579
- non coniferous. other	KTodm u.b.	40788	43194	44538	45038	46049	47380
Ratios							
- GS/Area	**Todm o.b./ha**	**71.30**	**76.76**	**82.89**	**89.73**	**100.68**	**103.67**
- NAI/GS	**Todm o.b./Todm o.b.**	**3.57**	**3.44**	**3.26**	**3.08**	**2.57**	**2.74**
- NAI/Area	**Todm o.b./ha**	**2.54**	**2.64**	**2.70**	**2.76**	**2.58**	**2.84**
- Fellings/NAI	**Todm o.b./Todm o.b.**	**72.00**	**71.76**	**71.41**	**70.89**	**76.19**	**70.25**
- Removals/Area	**Todm u.b./ha**	**1.46**	**1.53**	**1.55**	**1.58**	**1.59**	**1.62**

Source: PAJUOJA, H. (1995): The Outlook for the European Forest Resources and Roundwood Supply. ETTS V Working Paper. UN-ECE/FAO Timber and Forest Discussion Papers. UN. New York and Geneva