



WOOD FLOWS IN EUROPE

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COMMISSIONED BY

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INTRODUCTORY NOTES TO THE REPORT

This report is structured into three parts:

- 1. Conclusions**, with main results on policy related aspects and a condensed flow chart.
- 2. Summary**, explains the complete flow chart and main analysis results.
- 3. Methodology report**, includes a documentation of the used data in the wood flow analysis and explanations on the calculations.
- 4. Appendix**

Each part can be read separately, depending on the interest of the reader. However, some parts are repeated, because each part shall be complete and coherent in itself. Numbers in bold letters refer to numbers shown in the flow chart.

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1. CONCLUSIONS

PROJECT TARGET

All wood flows in Europe (EU27) are analyzed and presented in one single flow chart including material and energy consumption. In addition to the Wood Resource Balance sectors (EUwood 2010) the paper industry and recovered paper is included. Furthermore, an end-use-sector-analysis was added. The final flow chart shall show the relevance, measured in volume (m³ solid wood equivalents) of sectors and flows between sectors.

RESOURCE SECTOR

The theoretical biomass potential from European forests in 2010 accounted to **1,277 M m³ o.b.** per year, including stumps and bark. The growing stock including stumps is **21,021 M m³ o.b.** of which **731.0 M m³ o.b.** are available for wood supply (AWS).

From this point onwards all volumes were calculated in solid wood equivalents (swe). The final annual potential from forest results in **713.0 M m³ swe** available for wood supply. External trade of forest resources is relatively low.

The actual domestic use (consumption) based on the WRB 2010 was calculated with **543.7 M m³**. Thus removals correspond to **539.7 M m³**. This corresponds to 75.7% of the available potential. Thus, **173.3 M m³** remain in forests.

The forest industry is segmented (condensed) into the pulp- and paper industry and the wood industry (sawnwood, panel, other). Wood from trees used in the pulp and paper sector amounts to **107.8 M m³**, The wood industry uses **260.6 M m³** and **208.8 M m³** are incorporated in the energy sector.

SEMI-FINISHED PRODUCTS

The total resource consumption for the production of semi-finished products adds up to 456.7 M m³ (**141.8 M m³** for pulp and **314.9 M m³** for wood products). This includes 69.8 M m³ of industrial residues (**38.8 M m³ + 34.0 M m³**) and **15.5 M m³** of recycling material from wood products. However, the output of industrial residues is much higher. **176.3 M m³** or 38.6 % of the consumed resources are available as industrial residues for further processing in products or in energy. 157.2 M m³ come from semi-finished processes and **19.1 M m³** from finished processes.

FINISHED PRODUCTS

The total production of finished products adds up to 354.3 M m³ (**185.2 M m³** pulp and **169.1 M m³** wood products). **144.9 M m³** or 40.9% of the consumed resources are recycling products.

Another **113.6 M m³** or 32.1% is stored in use and contributes to carbon sequestration (104.0 M t CO₂). Thus, 73.0% of all fibrous material in the end-use sector market is recycled or stored in use.

337,2 M m³ of wood resources are used for energy consumption whereof 50.0% or **168.6 M m³** is burned in private households.

30.8% or **103.7 M m³** of all resources consumed for energy production comes from industrial residues of the forest industries.

168.6 M m³ wood from trees is used in biomass power plants. The proportion of the forest industries in this sector is 50.7% or **85.5 M m³**.

UTILIZATION FACTOR

Utilization factors simply calculate the relation between wood resources from trees and other wood resources in specific consumer sectors (energy, products). All factors in the following table, except H and J are such utilization factors.

CASCADE FACTOR

In the market process wood is used in cascades. A cascade use is defined as multiple use of the wood resources from trees by using residues, recycling (utilization in production) resources or recovered (collected after consumption) resources. The more often by

products and recycling products are used the higher the cascade factor gets. If only wood resources from trees and no other wood resources are used the cascade factor is 1,00. In Table 1 the cascade factors have been calculated for the wood resource balance as a whole (J) and for the wood industry (H). The overall cascade factor of the wood resource balance is **1.57**. Thus, the wood resources from trees have been use a bit more than one and a half time.

Table 1: Cascade factors for the wood resource balance and the wood sector

UTILIZATION FACTORS		TOTAL WOOD RESOURCE BALANCE			WOOD INDUSTRY	
	2010	M m ³	Factor	Calculation	M m ³	Factor
A	wood resources from trees	577.1			368.4	
B	residues in wood products	72.9	1.13	(A+B)/A	72.9	1.20
C	residues in energy	103.4	1.18	(A+C)/A		
D	recycling in products	130.2	1.23	(A+D)/A	130.2	1.35
E	recovery in energy	24.4	1.04	(A+E)/A		
F	residue utilization	176.3	1.31	(A+B+C)/A		
G	recycl. + revoc. cascades	154.6	1.27	(A+D+E)/A		
H	cascades in products	203.0	1.35	(A+B+D)/A	203.0	1.55
I	resid. + recycl. in energy	127.9	1.22	(A+C+E)/A		
J	total cascades	330.9	1.57	(A+H+I)/A		

Source:
Mantau, U.: *Wood flow analysis 2010*, Celle 2012

CASCADE FACTORS FOR BRANCHES

It would be interesting to calculate cascade factors for single branches, like paper or panel industry to document cascades effects within industries. However, cascades do not take place in one single sector, but between several sectors. E.g. the pulp industry receives chips from sawmills. While the use of recycled paper is a cascade within the sector and in the total wood resource balance, the purchase of chips by the pulp industry is a cascade in the total wood resource balance but not in the pulp industry itself. But wood industry does not receive any by-products or recycling products form energy uses. Therefore, a separate cascade factor for wood industry as a whole can be calculated. It is not very different from the overall cascade factor because almost all cascade uses take place in the wood industry sector.

UTILIZATION FACTORS FOR RESOURCES

The wood resource balance provides the opportunity to calculate utilization of residues and recycling resources by consumption. Utilization in products have a factor of 1.35 and the utilization factor for residues and recycling in energy production is 1.22.

WOOD INPUT-OUTPUT FACTOR

The wood input-output factor calculates how many times the wood resources from trees are used in the production process. The highest wood input-output factors are found in paper (2.38) and panel industry (2.43). The paper industry uses a high proportion of recycling products (2.06), while the panel industry intensively makes use of residues (2.02).

Table 2: Wood output-input factor for paper and panel products

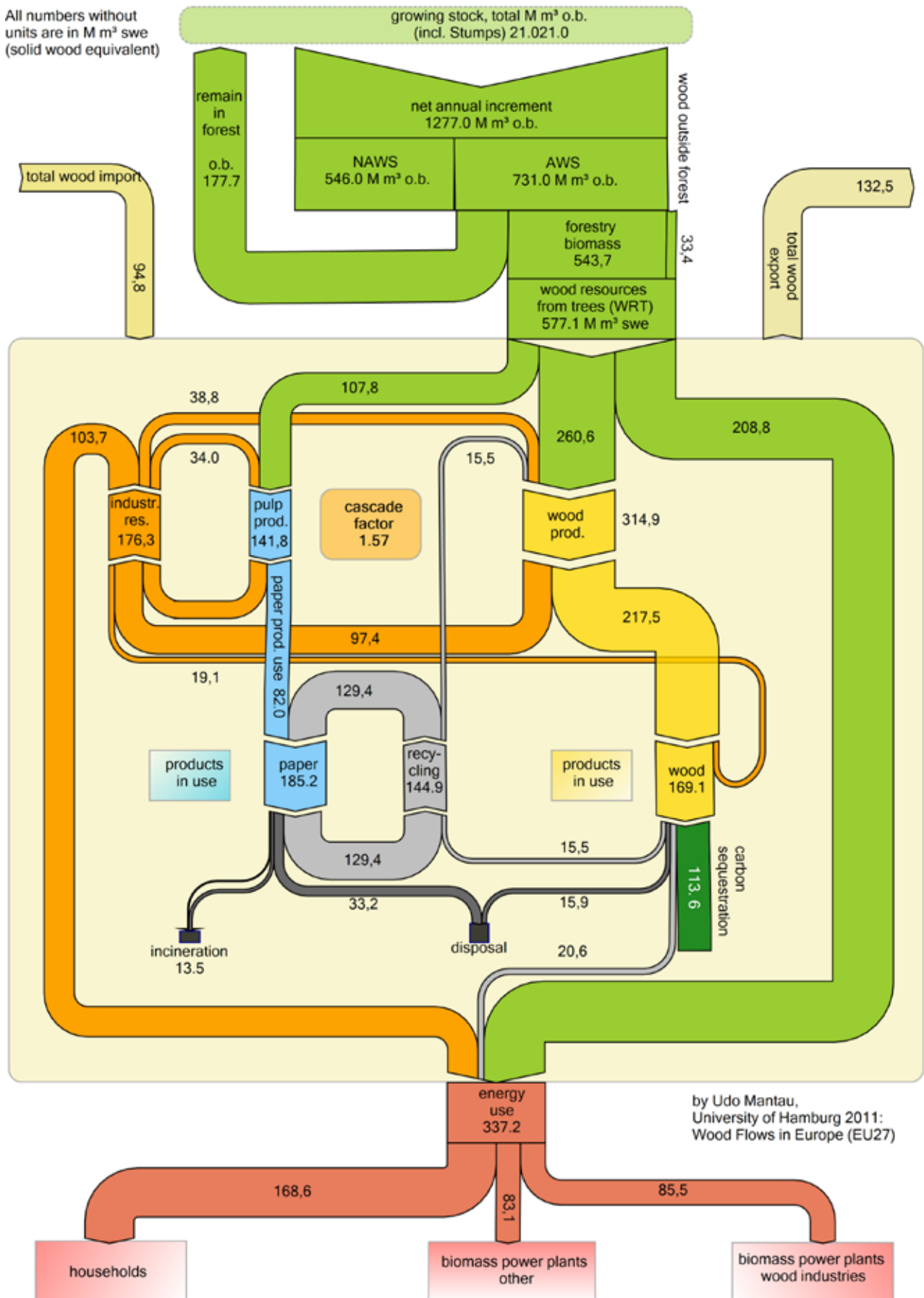
WOOD INPUT-OUTPUT FACTOR		PAPER		PANEL		CALCULATION
	2010	M m ³	Factor	M m ³	Factor	
A	wood resources from trees	107.8		38.0		
B	residues in zood products	34.0	1.32	38.8	2.02	(A+B)/A
C	recycling in products	114.7	2.06	15.5	1.41	(A+C)/A
D	cascades in products	148.7	2.38	54.3	2.43	(A+B+C)/A

Source:
Mantau, U.: *Wood flow analysis 2010*, Celle 2012



2. SUMMARY AND MAIN RESULTS OF THE WOOD FLOW ANALYSIS

Figure 1: Condensed wood flow chart from resource to end-use (EU27, 2010)



PROJECT TARGET

All wood flows in Europe (EU27) are analyzed and presented in one single flow chart (Figure 1). Thereby the material and energy consumption wood flows are shown. In addition to the Wood Resource Balance sectors (EUwood 2010) the paper industry and recovered paper will be included. Furthermore, an end-use-sector-analysis was added. The final flow chart shall show the relevance, measured in volume (m^3 solid wood equivalents) of sectors and flows between sectors.

If nothing else is mentioned in this report, all data in m^3 are solid wood equivalents (swe).

Data shown in the wood flow chart are printed in bold letters.

RESOURCE SECTOR

The theoretical biomass potential from European forests in 2010 accounted to **1,277 M m^3 o.b.** per year, including stumps and bark. The growing stock including stumps is **21,021 M m^3 o.b.** of which 731.0 M m^3 o.b. are available for wood supply (AWS).

From this point onwards all volumes were calculated in solid wood equivalents (swe). The final annual potential from forest results in **713.0 M m^3 swe** available for wood supply. External trade of forest resources is relatively low.

The actual domestic use (consumption) based on the WRB 2010 was calculated with **543.7 M m^3** . Thus removals correspond to **539.7 M m^3** . This corresponds to 75.7% of the available potential. Thus, **173.3 M m^3** remain in forests.

The total potential of landscape care wood and short rotation plantation is **87.5 M m^3** . Yet, it will take some time to utilize this potential. In the EUwood study it was assumed that currently **59.0 M m^3** are available. The calculations on the resource mix of energy consumers result in a current consumption of **33.4 M m^3** . Thus, the reserve is currently assumed with **25.6 M m^3** .

In the year 2010 the total consumption of wood resources from trees results in **577.1 M m^3** . This corresponds to a resource

453.4 M m^3 roundwood / stemwood (C+NC)

51.1 M m^3 bark

39.2 M m^3 forest residues

33.4 M m^3 other woody biomass

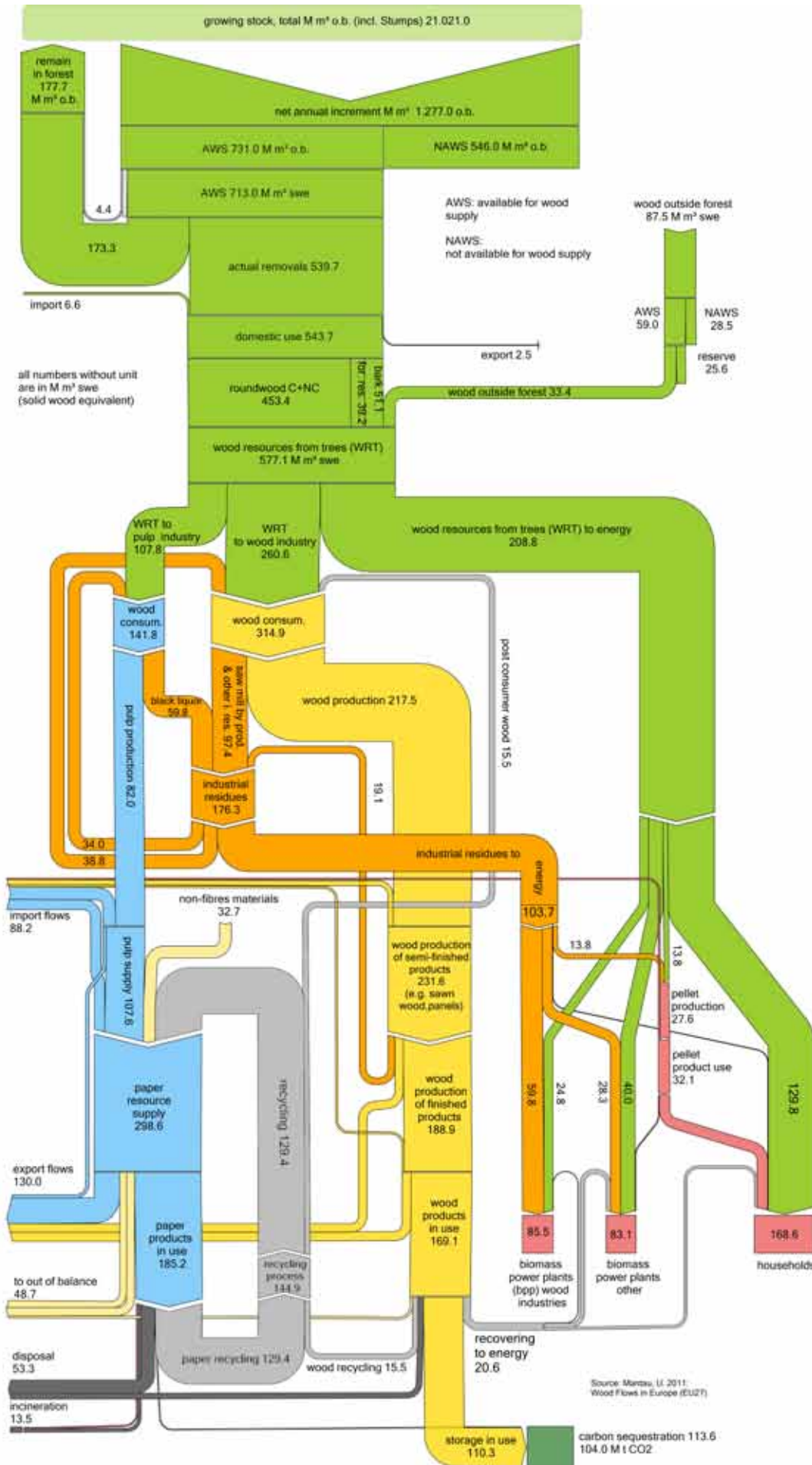
The forest industry is segmented (condensed) into the pulp- and paper industry and the wood industry (sawnwood, panel, other). Wood from trees used in the pulp and paper sector amounts to **107.8 M m^3** , The wood industry uses **260.6 M m^3** and **208.8 M m^3** are incorporated in the energy sector.

SEMI-FINISHED SECTOR AND INDUSTRIAL RESIDUES

The forest industry is segmented (condensed) into the pulp- and paper industry and the wood industry (sawnwood, panel, other). Wood from trees used in the pulp and paper sector amounts to **107.8 M m^3** , The wood industry uses **260.6 M m^3** . **208.8 M m^3** are incorporated in the energy sector.

The total wood fibre consumption of the pulp industry is **141.8 M m^3 swe** which includes **34.0 M m^3** industrial residues. From the total wood consumption the equivalent of **82.0 M m^3** is incorporated into pulp and **59.8 M m^3** swe is industrial residue (black liquor) (Figure 2). The latter is consumed for energy in wood industry biomass power plants.

Figure 2:
Wood flow
chart from
resource
to end-use
(EU27, 2010)



SEMI-FINISHED SECTOR AND INDUSTRIAL RESIDUES

The wood industry consumes **314.9 M m³ swe** (**260.6 M m³** wood from trees, **38.8 M m³** industrial residues and **15.5 M m³** post-consumer wood). From the total wood consumption the equivalent of **217.5 M m³** flows into the broad variety of wooden products and **97.4 M m³** swe are industrial residues. 39.8% of industrial residues (97.4 M m³ swe) are used in the wood production itself. The rest is used in other sectors. The total volume of industrial residues (**176.3 M m³**) includes the use of black liquor in the pulp and paper industry for heat and power generation. The wood consumption in the pulp industry for the year 2010 amounts to **141.8 M m³**.

TRADE

In comparison to the sum of all trade activities of the EU27 countries the trade volumes in this report are relatively small. The reason is that none of the internal trade between EU27 countries is represented in this flow chart. The overall import flows add up to 94.8 M m³ (**88.2 M m³ wood products** + **6.6 M m³ raw wood**). **132.5 M m³** are exported (**130.0 + 2.5 M m³**). Thus, the trade balance of external trade has a surplus of 37.7 M m³ in solid wood equivalents.

WOOD PRODUCTS IN THE SECTOR OF FINISHED PRODUCTS

The wood flow from the semi-finished sector into the finished sector starts with a resource input of **298.6 M m³** (swe) and **185.2 M m³** paper products in use. In the paper volume **32.7 M m³** non-fiber materials are included that originate from outside the calculated woody biomass flow. From the **185.2 M m³**, 33.2 M m³ is disposed and **13.5 M m³** are used for energy in incineration and biomass power plants. Another 2.9 M m³ is recycled otherwise, e.g. used for insulation in buildings. Therefore, it is added to the storage in use. **129,4 M m³** of paper products in use are recycled. Thus, around 70% of all paper product are recycled.

The wood products (sawnwood, panels, other) will be used in hundreds of finished products made of wood in the field of construction, furniture, packaging and others. However, as much as **188.9 M m³** will be used in one of the many production sectors of finished products. The sector of finished wood products has higher EU27 external exports (25.7 M m³) than imports (5.8 M m³). Thus, **169.1 M m³** contribute to the end-use market in the EU27.

PRODUCT TO USE

Consequently, on the domestic market **185.2 M m³** paper products and **169.1 M m³** wood products are available (Figure 2). Not all of this material can be stored or recovered. Examples for non collectable products are hygiene paper or tend sticks. CEPI estimates the proportion of non collectable paper with 8% of the products in use. The amount of paper & board (paper) that is non-recyclable and that is used for land filling or other recovery option has to be added to the amount of non-collectable paper. In total, this represents about 19% of the total paper volume put on the market. The percentage of respective non-recyclable wood products is unknown, but assumed to account for approximately 4%.

RECOVERY RATE AND STORAGE RATE PAPER SECTOR

69.9% of the “recovered paper at end users” are collected and sorted from households and others. 20.2% of the market volume for end user are disposed of and 13.5% are burned in incinerations or biomass power plants. 1.7% of the yearly paper products are used for other recycling options (construction), composting and other treatments. This volume is categorized as storage volume.

RECOVERY RATE AND STORAGE RATE WOOD SECTOR

In 2010 36.1 M m³ of the overall potential of post consumer wood (52.0 M m³) was recovered. Based on the total market volume of wood the recovery rate is 22.3% (9.2% material and 12.1% energy). Obviously, big proportions of the consumed wood are stored over a long time and are actually no potential for recycling. Based on the data for the year 2010, only one third of the wood consumption holds potential as post consumer wood. 66.9% of all wooden products in the end consumer market are stored in use.

CARBON SEQUESTRATION AND RECYCLING IN THE FOREST INDUSTRY

In 2010 the volume of all products of the pulp and wood industry in the EU27 was 354.5 M m³ swe. 32.0% (113.6 M m³) of this volume or the equivalent of **104.0 MtCO₂** (Figure 2) is stored in the long range. 47.8% percent of this volume is recovered (**129.4+15.5+20.6+3.8**). From all the products the forest industries deliver to the end-user markets 79.8% are stored in use or recovered.

CARBON SEQUESTRATION CALCULATION

In this study only the direct material effects of carbon sequestration for wood products stored in use are counted. The substitution effects of wood in comparison to other products are not considered. This effect can be a couple of times higher. Furthermore, the use of wood for bioenergy substitutes fossil energy fuels.

PELLETS

Energy use is largely end-use. Only producer of solid wood fuels manufacture products which are stored before they are finally consumed. In general, the storage time is less than one year. All pressed solid wood fuels like pellets, briquettes and other are named “pellets” in this study. The pellet production in the EU27 account for 14.8 M t or **27.6 M m³** swe (Figure 2). 4.7 M m³ of pellets are imported. Almost no extra trade exports are reported for the EU27 (0.1 M m³) which results in **32.1 M m³** pellet consumption. 1.5 M t (2.8 M m³ swe) of pellets is used in biomass power plants. Thus, 29.3 M m³ are used in households.

WOOD ENERGY IS END USE

The wood energy use is segmented into household consumption (**168,6 M m³ swe**) and the consumption of biomass power plants (168.6 M m³ swe). Half of the consumed wood is used in heat and in power plants of the wood industry itself (**85.5 M m³ swe**) and (**83.1 M m³**) in other biomass power plants. The total consumption in biomass power plants is 168.6 M m³ whereof the wood industry represents 50.7%.

The resources used are segmented in **208.8 M m³** wood from trees (forest, landscape care wood, short rotation plantations), **103.7 M m³** industrial residues (saw mill by products, black liquor, other industrial residues), **20.6 M m³** recycling resources (post consumer wood) and **32.1 M m³** pellets.



3. METHODOLOGY REPORT

DOCUMENTATION OF USED DATA IN THE WOOD FLOW ANALYSIS

RESOURCE SECTOR

PROJECT TARGET

All wood flows in Europe (EU27) are analyzed and presented in one single flow chart. Thereby the material and energy consumption wood flows are shown. In addition to the Wood Resource Balance sectors (EUwood 2010) the paper industry and recovered paper will be included. Furthermore, an end-use-sector-analysis was added. The final flow chart shall show the relevance, measured in volume (m³ solid wood equivalents) of sectors and flows between sectors.

GROWING STOCK AND STUMPS

Growing stock refers to the volume of wood, standing in the living trees as measured and reported by national and/or regional forest inventory according to a specific methodology. (UNECE, 2010)

The total growing stock in Europe (EU + EFTA) in the year 2010 is 17,912 M m³ o.b. (over bark m³ standing volume). This study focuses on EU27 in order to assure comparability with the results of the EUwood-study (EUwood, 2010). By subtracting the growing stock volume for Norway and Switzerland the respective number for the EU27 amounts to 16,604 M m³. According to projections with EFISCEN, the theoretical biomass potential from European forests in 2010 amounted to **1,277 million m³** per year, including stumps and bark in 2010 (Verkerk et al., 2010). About 52% of the total potential lies in stems, while logging residues and stumps represent 26% and 21%, respectively. Other biomass, i.e. stem and crown biomass from early thinning, represent only 1% of the total potential (Verkerk et al., 2010). To adapt the growing stock to the respective biomass including stumps a factor of 1,266 is applied. This means the respective value of 16,604 M m³ is **21,021 M m³** including stumps (Schelhaas et al, 2006).

NET ANNUAL INCREMENT (NAI)

Net Annual Increment refers to the average annual volume of gross increment minus natural losses on all trees over a given reference period as measured and reported by national and/or regional forest inventory according to a specific methodology.

Thus, the net annual increment covers only stemwood and not the total available biomass. In Schelhaas et al. (2006) it is calculated with 475.9 M m³ for Europe, which is the normal way to calculate forest potentials for the wood industry (stemwood).

For calculations on total wood availability, including energy, this is not an adequate value because the potential of residues and stumps is not included.

ANNUAL POTENTIAL

Therefore, in EUwood the annual potential was calculated differently (Verkerk et al. 2010). First, the maximum, theoretical availability of forest biomass from forests (**1,277 million m³**) available for wood supply in the 27 European Union (EU) member states was estimated by using the large-scale European Forest Information SCENario model (EFISCEN) (Schelhaas et al. 2007). These projections included stemwood, logging residues (i.e. stem tops, branches and needles), stumps, and other biomass (i.e. stem and crown biomass from early and/or pre-commercial thinnings).

Secondly, multiple environmental, technical and social constraints were defined and quantified to reduce the amount of biomass that can be extracted from forests for three mobilisation scenarios (see appendix).

Thirdly, according to EFISCEN the theoretical potential was combined with the constraints from three mobilisation scenarios to assess the realisable biomass potential from European forests. It should be noted that this figure only shows the potential of the forest and not a projection of supply.

Finally, some further calculations were undertaken, related to requirements for workforce and machinery in order to extract the realistic potential and to find out how procurement costs are affected by the different scenarios.

MOBILIZATION SCENARIOS

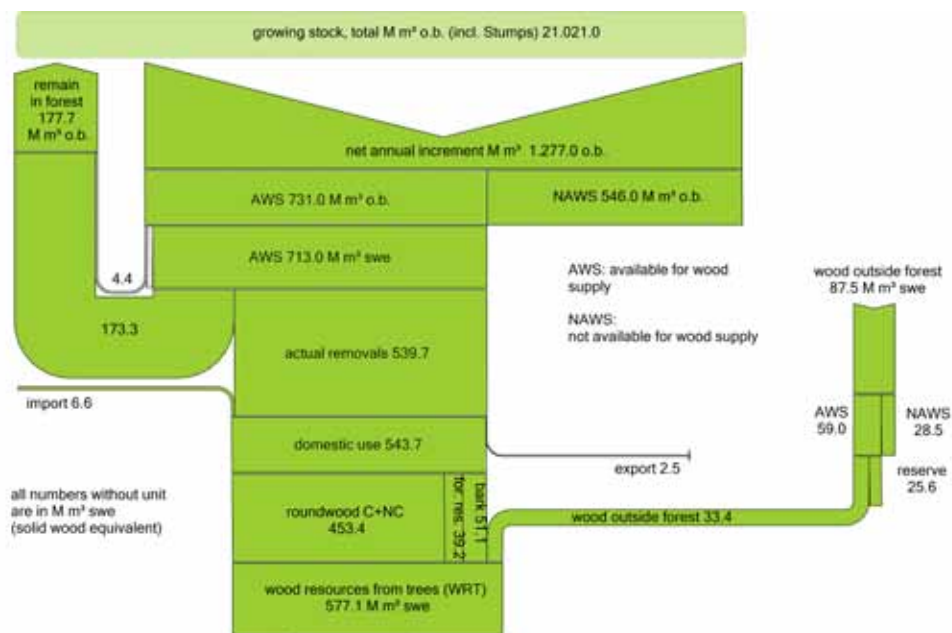
High scenario: strong focus on the use of wood for energy production and for other uses, effective implementation of current recommendations on wood mobilization

Medium scenario: represents more or less the state of the art of the actual mobilization or forest management; existing recommendations are not all fully implemented or do not have the desired effect

Low scenario: strong environmental concerns against the intensified use of wood and to forest owners who are more reluctant to harvest.

The following chart is a strongly reduced form of the undertaken calculations based on the medium mobilisation scenario.

Figure 3: Wood flow chart for the resource sector (EU27, 2010)



POTENTIAL OF MOBILIZATION SCENARIOS

The realistic biomass potential from forests under the medium mobilisation scenario is estimated at **731.0 M m³** per year over bark (ob) in 2010. However, if less strict restrictions on biomass extraction are assumed, the biomass potential from forest could be increased to 898 million m³ ob per year in 2030 according to the high mobilisation scenario. On the other hand, according to the low mobilisation scenario the biomass potential would be reduced to 625 million m³ ob per year in 2030 (Verkerk et al., 2010).

For flow chart calculation of a scenario most likely to occur, the medium mobilization scenario was applied, using **731.0 M m³** per year (ob) in 2010 as input.

All volumes were calculated in solid wood equivalents (swe). Stemwood was calculated without bark and bark was calculated in solid wood equivalents (conversion factor 0.75; UNECE 2010). Hence, the final annual potential from forest results in **713.0 M m³** available for wood supply. On the other hand **546.0 M m³** are not available for wood supply because of restrictions, especially concerning the harvest of stumps and residues.

REMOVALS AND WOOD SUPPLY

The actual domestic use (consumption) based on the WRB 2010 was calculated with **543.7 M m³**. This includes the trade surplus of 4.1 M m³ (Im-Ex). Thus, the actual removals correspond to **539.7 M m³** which corresponds to 75.7% of the available potential. This means **173.3 M m³ (swe)** or **177.7 M m³** o.b. remain in forests.

A special problem occurs when m³ are shifted from inventory data to consumption data, because bark is calculated in solid wood equivalent (swe). This causes a compression of the volume of 18.0 M m³ (731.0-713.0 M m³). 173.3 M m³ are not used from the actual cutting but when they are shifted back to standing volume, bark m³ swe turns back into bark m³. This means an expansion of **4.4 M m³** bark in natural volume.

The import data in this study are much lower than the sum of all EU27 countries because only extra-trade is calculated. The EU27 imports **6.6 M m³** of wood from countries outside the EU27 and exports **2.5 M m³**. Thus, the trade contributes with 4.1 M m³ to the raw wood consumption (**543.7 M m³ swe**).

OTHER BIOLOGICAL PRODUCTION

Other resources apart from biological production of wood fibers are landscape care wood and short rotation plantations. The latter is actually calculated with 0.5 M m³ in the EU27 and it is assumed that it is fully used. The total potential of landscape care wood is **87.5 M m³**. Yet, it will take some time to utilize this potential. In the EUwood study it was assumed that currently **59.0 M m³** are available. The calculations on the resource mix of energy consumer (see below) result in a current consumption of **33.4 M m³**. Thus, the reserve is currently assumed with **25.6 M m³**.

TRANSFER TO THE SEMI-FINISHED PRODUCT SECTOR

In the year 2010 the total consumption of wood resources from trees results in **577.1 M m³**. This corresponds to a resource

453.4 M m³ roundwood / stemwood (C+NC)

51.1 M m³ bark

39.2 M m³ forest residues

33.4 M m³ other woody biomass

SEMI-FINISHED PRODUCT SECTOR I

RESOURCE MIX OF PRODUCTS

COMPLEXITY

The semi-finished product sector is much more complex than the resource sector due to a broader variety of products in the statistical system.

TIME FRAME

The determination of the “base year” was a bit complicated. The project started to process all data for the year 2009, which represents the data availability at the beginning of the year 2011. In the calculation process it turned out that many of the calculations are based on the outcome of the EUwood-project. The consumption data of the EUwood project for the year 2010 are based on the forecasts for the industrial sector with existing data for 2007. The forecasts were quite good but some of the data for 2010 may not be the same as the upcoming real production for 2010. To prevent mixing data for different years, all data were calculated again for the year 2010. If actual data were not available, the data base of the EUwood-project for 2010 was applied.

RESOURCE MIX OF WOODY BIOMASS CONSUMER

Resource mix of woody biomass consumption yields important information for all calculations because it provides the basis for the calculation of consumption of each single resource. The following chapter gives an overview on the proportions of resources used in industrial sectors.

SAWMILL INDUSTRY

The sawmill industry uses 100% stemwood.

VENEER AND PLYWOOD

The veneer and plywood industry uses 100% stemwood.

PULP INDUSTRY

The wood consumption in the pulp industry for the year 2010 is based on the CEPI Annual statistics 2010. The pulp wood consumption for Norway and Switzerland was subtracted. As a result the wood consumption for pulp production was **141.8 M m³** for 2010. The proportion of mechanical to chemical pulp production in Europe (VDP 2011, p. 95) is 24% to 76%, which is assumed for EU27 as well.

PANEL INDUSTRY

The panel industry is defined as producer of particle board, fiber board (MDF) and oriented strand board (OSB). To calculate the average resource mix an average of these three products was taken into account for 2009. The basis for the calculation was the European Panel Federation (EPF) Annual Report 2009-2010 (p28+29). The weighted average of consumed resources (particle, MDF, OSB) is:

WOODY BIOMASS CONSUMPTION	
By assortments	%
Roundwood	41.2
By products	42.1
Post consumerwood	16.7
All	100.0

The particle board and MDF (medium density fibre board) industry uses proportions of bark (4%; UNECE/UFAO conversion) as well as branches or wood under 7 cm diameters (5% assumed for particle, 4% for MDF and 1% for OSB). Thus, in total 34.5% of round wood consumption is “real” industrial round wood, while 3.7% are branches (<7 cm; forest residues) and 3.0% is counted as bark.

WOODY BIOMASS CONSUMPTION FROM FORESTS	
By assortments	%
Wood in the rough	34.5
Wood under 7 cm diam.	3.7
Bark	3.0
Woody biomass from forests	41.2

RESOURCE MIX OF ENERGY USER THEORETICALLY ESTIMATED

In general, in all other sectors, particularly the energy consumers but the other material users as well, the resource mix is relatively unknown. However, resource mix proportions are limited by the total availability of resources minus the known proportions used in wood industry. Therefore, only the remaining volumes can be distributed. Furthermore, some plausible assumptions may be taken for specific consumers. It is also assumed that the total resource of bark, short rotation plantation wood, sawmill by-products, other industrial residues, black liquor and available post-consumer wood are totally consumed. Stemwood, forest residues and landscape care wood are not used up to the total potential. Under these constraints an optimization process was started which continued over the whole calculation period. Any change in a particular area may have an influence on the potential of available material for other sectors.

OTHER MATERIAL USES

The sector “other material uses” is differentiated into traditional other material uses and new innovative “other material uses”. Traditional other material uses include mulch, litter and other industrial round wood sorted for special purposes (e.g. poles, sleepers and posts for harbor works or fencing, which are significant uses in some areas). Many new innovative products made of wood fiber are on their way to gain market relevance, while their current market relevance is neglectable.

Empirical studies for the resource mix of other material uses are not available. However, some conclusions can be drawn from the products itself. Mulch is made from bark. Sleepers and posts are made from stemwood. It is assumed that the resource mix in this area shows 65% stemwood and 35% bark.

Table 3: Example for the optimization process; part II resource mix – absolute volumes

CONSUMER/RESOURCE	FOR	RES	PCW	SWF	OUT	ALL
Wood	260.6	38.8	15.5	0.0	0.0	314.9
Pulp	107.8	34.0	0.0	0.0	0.0	141.8
BPP, forest industry	24.8	59.8	0.9	0.0	0.0	85.5
BPP, other	40.4	28.3	12.1	2.5	0.0	83.3
households	129.8	1.5	7.7	29.3	15.5	183.8
pellets	13.8	13.8	0.0	0.0	0.0	27.6
TOTAL	577.1	176.3	36.1	31.8	15.5	836.8

FOR = wood from trees;
RES = industrial residues;
PCW = post consumer wood;
SWF = solid wood fuels;
OUT = other resources

MATRIX APPROACH

To obtain the most realistic resource mix distribution of the energy user a matrix approach was chosen for the estimation process. The lines of the matrix represent the consumer of woody biomass and the columns represent the resources. The data base of the material user is relatively well known. Furthermore, the overall available potential of the resources are well known. Therefore, the maximum sums of usable resources are known as well. "The more and better we know, the entirely and better we can estimate the unknown!"

CALCULATION THE UNKNOWN

In some countries, especially in Germany, many studies have been established to calculate the resource mix of all woody biomass consumers (resource monitoring by Mantau). If no country specific data are available, these numbers are the starting point for the expert estimations for the resource mix of energy consumer. The estimation process is carried out within the borderlines of the maximum potential of resources and the already used potential by wood industry. It is further restricted by the plausible assumptions that the total resource for bark, short rotation plantation, sawmill by products, other industrial residues reduced, black liquor and available post-consumer wood is totally consumed.

USED POTENTIAL

The following table shows the available potential of a resource sector (POT) and the used volume (CON, consumption). The use factor (FAC) represents the proportion used of a resource. It cannot be higher as 1,00. For all sectors with the factor it was assumed that all the usable potential is consumed. The usable potential is lower than the theoretical potential. The latter is higher for all biologically produced resources and for post-consumer wood.

Table 4: Example for the optimization process; part III control table of used resources (ongoing)

REGION EU 27			
POTENTIAL 2010	POT	CON	FAC
in M m ³			
Sternwood C, ME	361.8	544.1	
Sternwood NC, ME	182.3	453.4	0.83
Forest residues C+NC, ME	118.0	39.2	0.33
Bark, C+NC, ME	50.9	51.1	1.00
Landscape care wood (USE) M	58.5	32.9	0.56
Short rotation plantation	0.5	0.5	1.00
Sawmill by products (POT)	86.6	86.7	1.00
Other ind. res. reduced (POT)	29.7	29.8	1.00
Black liquor (POT)	59.6	59.8	1.00
Post-consumer wood (POT)	36.1	36.1	1.00
Solid wood fuels (POT)	31.8	31.8	1.00
TOTAL	1,015.8	821.4	0.81

C = conifers;
 NC = non-conifers;
 ME = medium mobilization
 scenario EUwood 2010;
 POT = potential (available)

ALL PRODUCTS

TRADE DATA

EXTRA TRADE

The overall trade volume of all EU27 countries is quite high due to their high internal trade volume. For the purpose of this study only the extra-trade is relevant. Thus, only trade flows between the EU27 and countries outside the EU27 are calculated.

FROM 100 KG TO M³

All trade data from EUROSTAT are reported in value, weight (100 kg) and a supplementary quantity. This is of course a problem of conversion because all calculations shall be done in m³ swe. The approach to use the supplementary quantity (reported in EUROSTAT) in order to determine conversion factors between kg and m³ failed. Thus, the conversion factors were calculated based on existing conversion factors (UNECE, 2010) and further assumptions. To analyze conversion factors in detail was not in the scope of this project. However, we do not expect relevant deviations from the true values. All conversion factors used in this calculation are published in the following tables.

ROUND WOOD

The conversion factor of round wood was calculated on the basis of the shipping weight (UNECE, 2010) for conifers and non-conifers; both fuelwood (20%) and industrial round wood (80%). Thus, the green weight of conifers is 920 kg/m³ and of non-conifers are 1,087 kg/m³. Some calculations have been done on the proportion of fuelwood and industrial round wood (C+NC). However, the overall proportion is almost exactly 50% for both. As a consequence, a conversion factor of almost 1 was used (0.996). A conversion factor of 1.285 was chosen to transfer t into m³ (swe). As a result of these calculations the EU27 imports of round wood are 6.611 M m³ swe and the exports are 2.530 M m³. The net imports from outside the EU27 are 4.081 M m³ swe.

Table 5: Extra-trade from EU27 of round wood in M t and converted m³ swe

RESOURCES - ROUNDWOOD	EUROSTAT REPORTED VOLUME			CONVERSION	CONVERTED VOLUME IN SWE		
	Import in M t	Export in M t	Net trade in M t	Factor M m ³ / M t	Import M m ³ swe	Export M m ³ swe	Net trade M m ³ swe
2010							
Fuelwood (stem) 4401 10 00	1.160	0.179	-0.981	1.285	1.490	0.230	-1.260
Industr. roundw. 4403	3.985	1.790	-2.195	1.285	5.121	2.300	-2.821
Total roundwood	5.145	1.969	-3.176	1.285	6.611	2.530	-4.081

Source:
Own calculations based
on UNECE/Fonseca:
Conversion factors

SEMI-FINISHED PRODUCTS

The following table represents the used conversion factors for the products in the first column. Basically, they are calculated on the product conversion factors (UNECE, 2010; EUwood 2010) and partly combined with a weighted average of the ingoing market volumes (C+NC). Conversion factors are often based on weighted averages between different commodities. This makes the topic of conversion factors so problematic, because they may change with market changes. This is also the reason why their plausibility decreases with the level of aggregation. Having this in mind, the total conversion factor for all semi-finished products (3.029 m³/t) might be considered interesting information, but it is always more precise to use conversion factors as specifically as possible.

Table 6: Extra-trade from EU27 of semi-finished products in M t and converted m³ swe

SEMI-FINISHED PRODUCTS	EUROSTAT REPORTED VOLUME			CONVERSION	CONVERTED VOLUME IN SWE		
	2010	Import in M t	Export in M t	Net trade in M t	Factor M m ³ / M t	Import M m ³ swe	Export M m ³ swe
Sawnwood 4407	5.207	9.166	3.959	1.770	9.216	16.223	7.007
Veneer+plywood 4408	0.281	0.074	-0.207	1.574	0.442	0.116	-0.326
Particl + OSB* 4410	0.525	2.195	1.669	1.550	0.814	3.402	2.588
Fibreboard 4411	0.375	2.426	2.051	1.395	0.523	3.383	2.861
Plyw. Panel 4412	1.964	0.281	-1.683	1.574	3.091	0.443	-2.648
Wood products	8.352	14.141	5.789	1.674	14.086	23.567	9.481
Pulp 4701-06	9.002	2.383	-6.619	3.870	34.837	9.223	-25.614
Recov. paper 4707	1.364	10.228	8.864	3.400	4.636	34.775	30.139
Paper 48	8.037	19.848	11.811	3.600	28.934	71.451	42.518
Paper products	18.402	32.459	14.056	3.615	68.407	115.449	47.43
SEMI-FINISHED TOTAL	26.755	46.600	19.845	3.020	82.493	139.016	56.524

Source:

Own calculations based on UNECE/Fonseca: Conversion factors

M³ TO M³ OR T TO M³

One should bear in mind that in the calculations of the wood resource balance the transformation from 1 m³ of a product fibre board (MDF) into solid wood equivalents (1.799) is different from the calculation from traded tons into m³. A heavy product with a condensed wood density (MDF) has a lower conversion factor than a product with a normal density (sawnwood, 1.770) which represents more cubic meter per ton. In contrast, the conversion factor for sawnwood in the wood resource balance would be 1.000. It is an expansion factor from mass to volume.

FINISHED PRODUCTS

The level of aggregation of different resources increases normally with the production level. On the other hand, almost no conversion factors are available for the extremely high variety of finished products. A very simple assumption was taken for the product categories in the following table: The conversion factor of finished wooden products is based on the conversion factor of sawnwood (1.770). "Strips" are made from sawnwood and are not mixed with other materials (1.770). "Packaging" is very similar to sawnwood. The proportion of panels leads to a lower conversion factor as well as the mixture with other materials. This is also the case for all other finished products but with a higher proportion of other materials. Therefore, the conversion factor of sawnwood is decreased by 15% for "packaging", by 25% for "building materials" and by 35% for furniture and other.

Table 7: Extra-trade from EU27 of round wood in M t and converted m³ swe

FINISHED PRODUCTS	EUROSTAT REPORTED VOLUME			CONVERSION	CONVERTED VOLUME IN SWE		
	2010	Import in M t	Export in M t	Net trade in M t	Factor M m ³ / M t	Import M m ³ swe	Export M m ³ swe
Strips 4409	0.500	1.383	0.882	1.770	0.885	2.447	1.562
Building mat. 4418+9406	0.738	12.343	11.605	1.327	0.980	16.385	15.405
Packaging 4415	0.259	3.263	3.004	1.504	0.390	4.909	4.519
Furniture 94	2.499	1.677	-0.822	1.150	2.875	1.930	-0.946
Other 4420/21	0.607	0.000	-0.607	1.150	0.698	0.000	-0.698
FINISHED	4.604	18.666	14.062	1.354	5.829	25.671	19.841

Source:

Own calculations

SEMI-FINISHED PRODUCT SECTOR II

WOOD FLOW DESCRIPTION

COMPLEXITY REDUCTION

The flowchart of the semi-finished product sector is condensed to two main flows, the pulp and paper flow and the flow of wooden products. The latter is the sum of all wooden product industries (sawnwood, veneer and plywood, panels and other material uses (pools, sleepers, dissolving pulp et al.) and producing industries. However, the basic calculations are done for each single sector because the resource mix of the sectors varies a lot. Furthermore, the wood flows of industrial residues and the recycling streams are part of the total picture. However, the total wood flows are too complex to be shown in one flow diagram. Consequently complexity is reduced.

ENERGY SECTOR

The energy sectors are end use sectors and therefore do not really belong to the semi-finished product sector. However, from the calculation point of view they are directly connected with the resource sectors. Only pellets are an energy product that is finally consumed by one of the wood energy sectors.

CONDENSED FLOW CHART

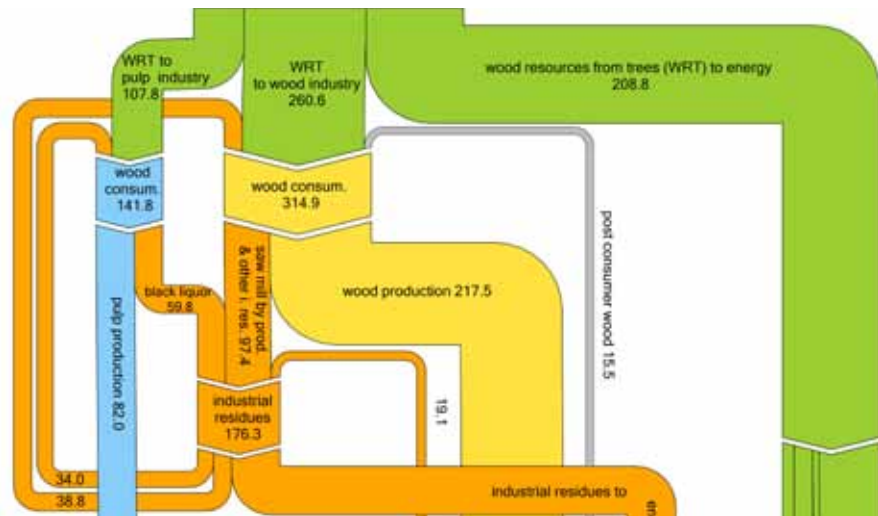
The wood flow of wood from trees streams into the pulp and paper sector with **107.8 M m³**, the wood industry with **260.6 M m³** and into the energy sector with **208.8 M m³**. The pulp industry consumes **141.8 M m³** swe (**107.8 M m³** wood from trees and **34.0 M m³** industrial residues). From the total wood consumption the equivalent of **82.0 M m³** flows into pulp and **59.8 M m³** swe is industrial residue (black liquor). The latter is consumed for energy in wood industry biomass power plants.

The wood industry consumes **314.9 M m³ swe** (**260.6 M m³** wood from trees, **38.8 M m³** industrial residues and **15.5 M m³** post-consumer wood). From the total wood consumption the equivalent of **217.4 M m³** flows into the broad variety of wooden products and **97.4 M m³** swe are industrial residues (sawmill by products, other industrial residues from semi (157.2 M m³) and finished production processes (**19.1 M m³**). 39% of industrial residues (97.4 M m³ swe) are used in the wood production itself. The rest is used in other sectors. The total volume of industrial residues (**176.3 M m³**) includes the use of black liquor in the pulp and paper industry for heat and power generation as well as respective plants in the sawmill and panel industry. Including the internal use of black liquor as "internal" wood industry use, the percentage of the internal use of industrial residues is already 75%. The internal power and heat use in the wood industry cannot be separated as well, but most likely the overall internal use of industrial residues in the forest industry is higher than 80%.

TRADE

The trade volumes are relatively small. The overall trade activity of the EU27 countries is much higher. However, all internal trade is not represented in this calculation. Pulp industry is importing (34.8 M m³ swe) much more than exporting (9.2 M m³ swe). While the trade balance of the pulp industry is negative, the trade balance of the wood industry is positive. 14.1 M m³ are imported and 23.6 M m³ are exported outside the EU27.

Figure 4: Wood flow chart for the semi-finished product sector (EU27, 2010)



RECYCLING

Woody biomass is a perfectly recyclable product. The recycled amount of the overall recyclable potential depends very much on the effectiveness of the collecting system. The recovery rate for paper in the EU27 is about 74% and has thereby reached almost its technically possible maximum. The recovery rate for post consumer wood in Europe is very diverse. While in some countries the recovery rate has almost reached its maximum other countries are still building up their collecting systems. However, from the overall potential of 58.5 M m³ in 2010 (EUwood, 2010) 62% (36.1 M m³) are already recovered.

FINISHED PRODUCT SECTOR

WOOD FLOW DESCRIPTION

WOOD PRODUCTS IN THE SECTOR OF FINISHED PRODUCTS

The wood flow from the semi-finished sector into the finished sector starts with a resource supply of **298.6 M m³** (swe) of paper products and **188.9 M m³** (swe) of wood products. In the paper volume **32.7 M m³** non-fiber materials are included. The paper products in use are **185.2 M m³**, whereof 18 M m³ is non collectable material. The overall potential for paper recycling is 167.2 M m³. 33.2 M m³ are disposed of, 9.7 M m³ are burned in incineration plants and 3.8 M m³ is used for energy production in biomass power plants. As a result, **129.4 M m³** of all paper products are recycled and reused in paper production. Another 2.9 M m³ is otherwise recycled like for insulation in buildings. Therefore, it is added to the storage in use.

The wood products (sawnwood, panels, other) will be used in hundreds of finished products made of wood in the field of construction, furniture, packaging and others. However, not more or less than 188.9 M m³ will be used somewhere in the many production sectors of finished products. The statistical challenge lies in imports and exports. As described in the chapter “trade data” all relevant products made of wood have been considered and the trade statistic, reporting in units of 100 kg was converted into solid wood equivalents using conversion factors.

TRADE VOLUME

The overall target of the project is the calculation of the wood flows of the EU27. Thus, only the EU27 extra trade was considered in these calculations because internal trade between EU27 countries does not change the quantity of the wood flow of the EU27 as a whole. The forest industries together export **130.0 M m³**. The total imports count for 88.2 M m³ (excluding pellet import), which results in an overall net export of 41,8 M m³.

Extra-trade from EU27 of round wood in M t and converted m³ swe

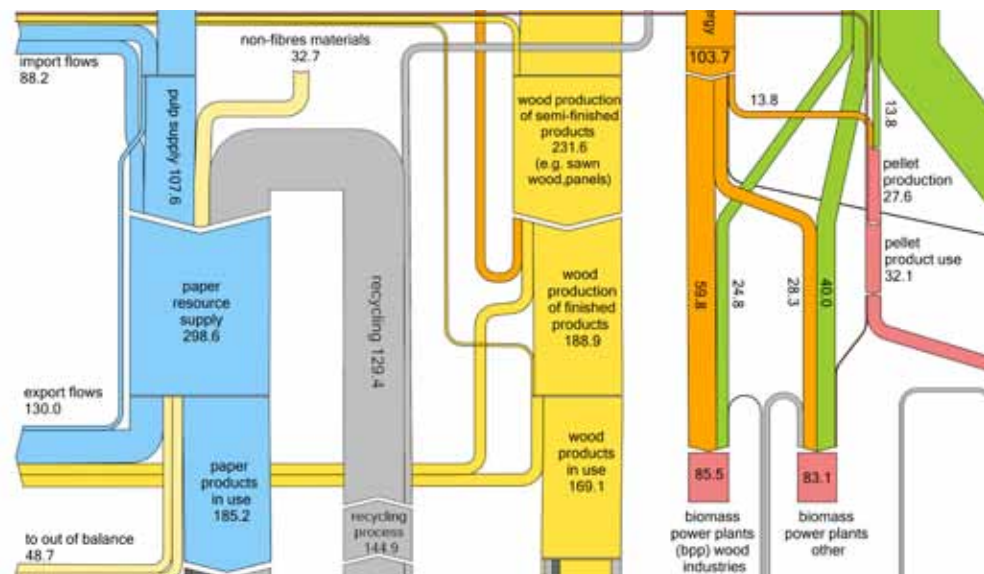
FINISHED PRODUCTS	EUROSTAT REPORTED VOLUME			CONVERSION	CONVERTED VOLUME IN SWE		
	Import in M t	Export in M t	Net trade in M t	Factor M m ³ / M t	Import M m ³ swe	Export M m ³ swe	Net trade M m ³ swe
2010							
Strips 4409	0.500	1.383	0.882	1.770	0.885	2.447	1.562
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Furniture 94	2.499	1.677	-0.822	1.150	2.875	1.930	-0.946
Other 4420/21	0.607	0.000	-0.607	1.150	0.698	0.000	-0.698
FINISHED	4.604	18.666	14.062	1.354	5.829	25.671	19.841

Further comments see chapter “trade data”

PRODUCT TO USE

The availability on the domestic market is **185.2 M m³** paper products and **169.1 M m³** wood products. Not all of this material can be stored or recovered. Examples for non collectable products are hygiene paper or tend sticks. CEPI estimates the proportion of non collectable paper with 8% of the products in use. Nothing is known about the same proportion for wood products. It is assumed that the proportion is only half as big (4%).

Figure 5: Wood flow chart for the finished product sector (EU27, 2010)



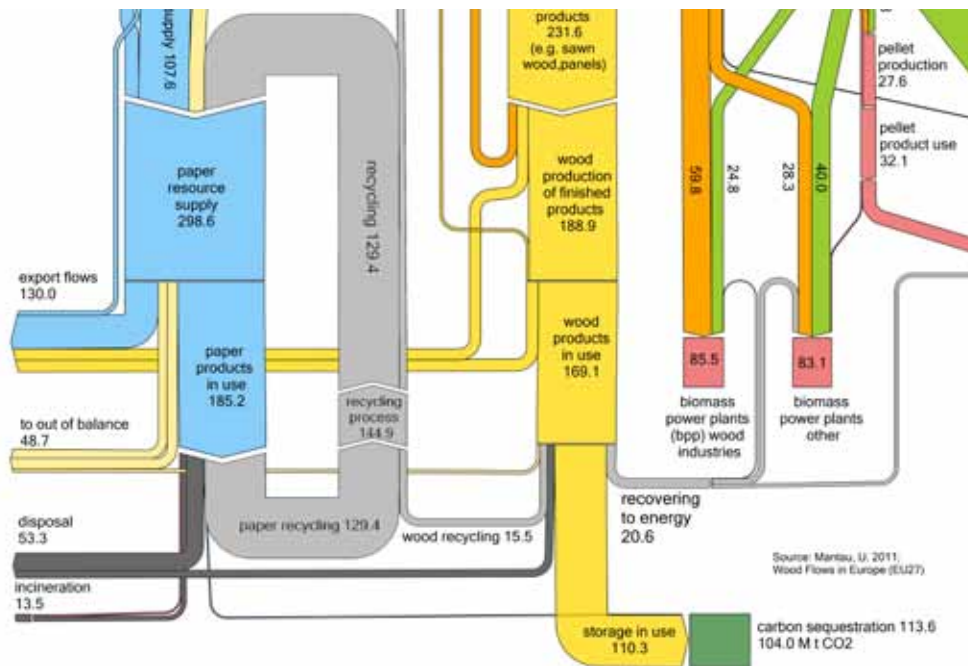
RECOVERY RATE AND STORAGE RATE WOOD PRODUCTS

The recovery rate of paper (market supply) is 69.9%. The same proportion is used for the volume of recovered paper (fibre). 20.2% of the market volume for end user is disposed of and 8.2% is burned in incinerations or biomass power plants. 1.7% of the yearly paper products are used for other recycling options (construction), composting and other treatments. This volume is categorized as storage volume.

The recovery rate of wooden products can be calculated in different ways. One possibility is the overall potential of post consumer wood. This was calculated in EUwood with 52.0 M m³ in 2010. The volume is based on potential studies in some countries. 36.1 M m³ was used in 2010. Obviously, big proportions of the consumed wood are stored over a long time and are actually no potential for recovery. Based on the data for the year 2010 only one third of the wood consumption is a potential for post consumer wood. 68.0% of all wooden products in the end consumer market are stored in use.

CARBON SEQUESTRATION OF WOOD PRODUCTS

In this study only the direct material effects of carbon sequestration for wood products stored in use are counted. The substitution effects of wood in comparison to other products are not considered. This effect can be four times higher. Furthermore, the use of wood for bioenergy substitutes fossil energy fuels.

Figure 6: Wood flow chart Recycling, disposal and storage in use (CO₂), (EU27, 2010)

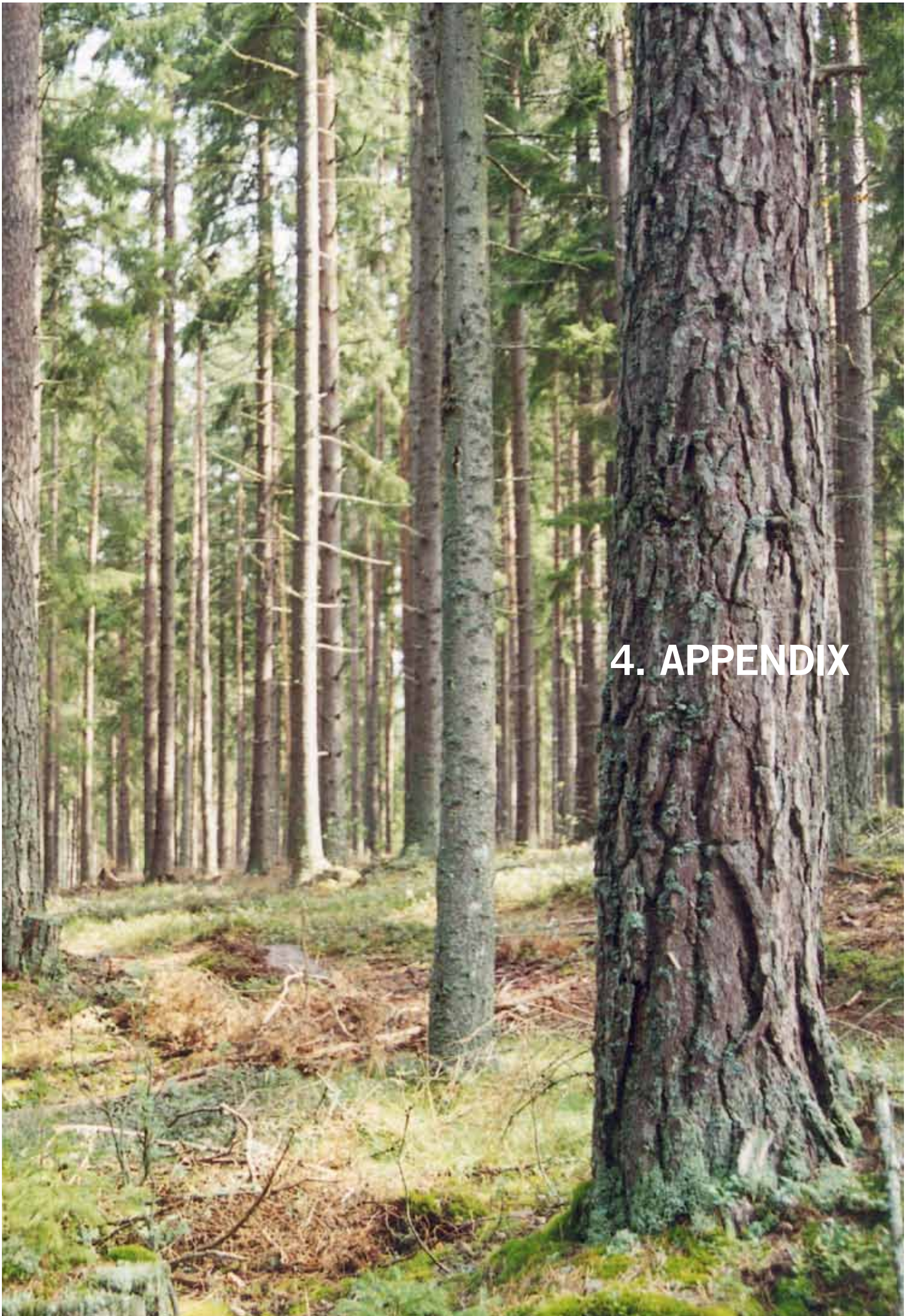
PELLETS

Energy use is largely end-use. Only producer of solid wood fuels manufacture products which are stored before they are finally consumed. In general, the storage time is less than one year. All pressed solid wood fuels like pellets, briquettes and other are named “pellets” in this study. The pellet production in the EU27 account for 14.8 M t (AEBIOM 2011). Moisture of 8.5% and a weight of 493 kg/m³ (UNECE, 2010) were assumed, which results in **27.6 M m³ swe** (conversion factor 1.856). 4.7 M m³ of pellets are imported. Almost no extra trade exports are reported for the EU27 (0.1 M m³) which results in **32.1 M m³** pellet consumption. AEBIOM (2011) reports that 1.5 M t (2.8 M m³ swe) of pellets is used in biomass power plants. Thus, 29.3 M m³ are used in households.

WOOD ENERGY END USE

The wood energy use is segmented into household consumption (**168.6 M m³ swe**) and the consumption of biomass power plants (168.6 M m³ swe). Half of the consumed wood is used in heat and power plants of the wood industry itself (**85.5 M m³ swe**) and (**83.1 M m³**) in other biomass power plants. Wood industry represents 52% of the total consumption in biomass power plants.

The resources used are segmented in **208.8 M m³** wood from trees (forest, landscape care wood, short rotation plantations), **103.7 M m³** industrial residues (saw mill by products, black liquor, other industrial residues), **21.4 M m³** recycling resources (post consumer wood, recovered paper) and **32.1 M m³** pellets.



4. APPENDIX

Constraints on biomass supply from forests (excerpt from Mantau, EUwood 2010)

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The theoretical forest biomass potentials estimated by EFISCEN are higher than what can actually be supplied from the forest due to various environmental, social, technical, and economic constraints. The constraints on wood mobilisation applied in this study have been identified in different international processes, in which recommendations have been developed to overcome these constraints. These recommendations serve as a starting point for the mobilisation scenarios defined in this study. The scenarios project different degrees of success of how the recommendations will be implemented. The scenarios are defined as follows:

In the **high mobilisation scenario** there is a strong focus on the use of wood for producing energy and for other uses. Recommendations by the abovementioned processes have been successfully translated into measures that lead to an increased mobilisation of wood. This means that new forest owner associations or co-operations are established throughout Europe. Together with existing associations, these new associations lead to improved access of wood to markets. In addition, strong mechanisation is taking place across Europe and existing technologies are effectively shared between countries through improved information exchange. Biomass harvesting guidelines will become less restricting, because technologies are developed that are less harmful for the environment. Furthermore, possible negative environmental effects of intensified use of forest resources are considered less important than the negative effects of alternative sources of energy (i.e. fossil fuels) or alternative building materials (e.g. steel and concrete). Application of fertiliser is permitted to limit detrimental effects of logging residue and stump extraction on the soil.

The **medium mobilisation scenario** builds on the idea that recommendations are not all fully implemented or do not have the desired effect. New forest owner associations or co-operations are established throughout Europe, but this does not lead to significant changes in the availability of wood from private forest owners. Biomass harvesting guidelines that have been developed in several countries are considered adequate and similar guidelines are implemented in other countries through improved information exchange. Mechanisation of harvesting is taking place, leading to a further shift of motor-manual harvesting to mechanised harvesting. To protect biodiversity forests are being protected, but with medium impacts on the harvests that can take place. Application of fertiliser is permitted to limited extent to limit detrimental effects of logging residue and stump extraction on the soil.

In the **low mobilisation scenario**, the recommendations do not have the desired effect, because the use of wood for producing energy and for other uses is subject to strong environmental concerns. Possible negative environmental effects of intensified use of wood are considered very important and lead to strict biomass harvesting guidelines. Application of fertiliser to limit detrimental effects of logging residue and stump extraction on the soil is not permitted. Forests are set aside to protect biodiversity with strong limitations on harvest possibilities in these areas. Furthermore, forest owners have a negative attitude towards intensifying the use of their forests. Mechanisation of harvesting is taking place, leading to a shift of motor-manual harvesting to mechanised harvesting, but with little effect on the intensity of resource use.

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31st of Mai 2012