EFORWOOD
Sustainability Impact Assessment
of the Forestry - Wood Chain

Project no. 518128

EFORWOOD

Tools for Sustainability Impact Assessment

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ABSTRACT

This deliverable is part of an EU project called EFORWOOD. Aim of EFORWOOD is to provide methodologies and tools that will integrate Sustainability Impact Assessment of the whole European Forestry Wood Chain (FWC). The object of this report is to present typical manufacturing processes for fibre chain, solid wood chain and bioenergy chain. These typical processes are called model mills and they have been described earlier in deliverable *PD4.1.7 Report describing the model mills in the case studies*. This report differs from the previous report in the level of numerical detailed information concerning the mills. The model mills are assumed to be similar in country groups that have been defined for different regions of Europe. The differences between these European regions are described and discussed in this report.

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1 Introduction

This report is part of an EU project called EFORWOOD, which aims to provide methodologies and tools that will integrate Sustainability Impact Assessment of the whole European Forestry Wood Chain (FWC). This deliverable has been done by Module 4, which consists of European companies focused on processing and manufacturing stages of FWC in Europe.

This report is aimed to give a more complete overview of the process information for the manufacturing model processes that were first described in report *PD4.1.7 Report describing the model mills in the case studies*. In the present report the focus is on the EU-FWC whereas in PD 4.1.7 the focus was on the case studies within the EFORWOOD project.

M4 is dealing with the manufacturing processes within EFORWOOD. Three different value chains are studies for the industrial processes; the Fibre chain, the Solid wood chain and the Bioenergy chain. The model processes included in each value chain are further described below. The selected model processes have been based on statistic from Jaakko Pöyry database and covers about 60-80% of the total production within each value chain.

Details discussed in this report are based on the general description of the model processes given in report PD 4.1.7. Not all information was available for all processes in all studied regions, and as already pointed out earlier; in reality all mills are unique.

Within the defined 4 European regions, the industries are assumed to have the same level of technology in the processes, the same production capacity (size) and the same use of raw material. The model mills that are studied in each European region are chosen so that about 60-80% of the production is covered in each region. The regions and model processes have been defined to make the indicator data collection for the manufacturing processes in the EFW chain possible. In cases where country-specific data are not available an assumption is used by applying the data for another country in the same region.

The defined regions include the following countries:

Fibre value chain

Western and Central Europe	Nordic countries	Southern Europe	Eastern Europe
AUSTRIA	FINLAND	CYPRUS	CZECH REPUBLIC
BELGIUM	NORWAY	GREECE	BULGARIA
DENMARK	SWEDEN	ITALY	ESTONIA
FRANCE		MALTA	HUNGARY
GERMANY		PORTUGAL	LATVIA
IRELAND		SPAIN	LITHUANIA
NETHERLANDS			POLAND
SWITZERLAND			ROMANIA
UNITED KINGDOM			SLOVAK REPUBLIC

Solid wood chain

Central and Southern Europe	Nordic countries	Eastern Europe
AUSTRIA BELGIUM CYPRUS DENMARK FRANCE GERMANY GREECE IRELAND ITALY MALTA NETHERLANDS PORTUGAL SPAIN SWITZERLAND UNITED KINGDOM	FINLAND NORWAY SWEDEN	CZECH REPUBLIC BULGARIA ESTONIA HUNGARY LATVIA LITHUANIA POLAND ROMANIA SLOVAK REPUBLIC

Bioenergy chain (pellets production)

Central and Eastern Europe	Nordic countries	Southern Europe
AUSTRIA ESTONIA GERMANY NETHERLANDS POLAND	DENMARK FINLAND SWEDEN	ITALY

For the value chains, the industrial processes within the 4 regions that are being studied and further described in this report are:

Fibre value chain

- Integrated Newsprint
- Woodcontaining magazine paper
- Woodfree fine paper
- Containerboard
- Cartonboard
- Market pulp (Bleached chemical pulp)

Solid Wood Chain

- Saw Milling (hardwood and softwood sawn timber)
- Wood-based panels (plywood and particle board)
- Joinery (windows)
- Building components (roof trusses, houses)

Bioenergy

- Pellets

Contributors and responsibilities in this report

Fibre value chain

STFI-PF Data collection for Integrated newsprint, Containerboard, and Cartonboard

KCL Data collection for Woodcontaining magazine paper, Woodfree fine paper, and Market pulp

Solid wood chain

BRE Data collection for the region Central and Southern Europe

VTT Data collection for the region Nordic countries

TUZVO Data collection for the region Eastern Europe

Bioenergy

VTT Data collection and discussion for the total Bioenergy chain, focusing on pellets.

The report was assembled and finalized by **KCL**.

2 The Fibre value chain

2.1 Data collection and detail sheets

The industrial processes in the fibre value chain were described very detailed based on model mill concepts in report PD 4.1.7. The used raw materials in the pulp and paper processes – PGW (pressure groundwood), TMP (thermomechanical pulp), kraft pulp and recycled pulp are also described in detail in the respective report and will be the same in this report PD 4.1.9 as in the previous report PD 4.1.7.

The total production capacities of the regions are summarized in **table 1**.

Table 1. Total production capacity of paper, board and market pulp in the regions

	Western and Central Europe	Nordic countries	Southern Europe	Eastern Europe
Paper and board, kt/a	45000	27000	16000	4600
Market pulp, kt/a	2800	7500	2300	700

For the fibre value chain, detailed information was collected for the 6 different processes (**table 2)**.For the paper production processes, this information contains data about stock preparation, paper manufacturing, energy, environmental and sustainability; and it is assembled in so-called detail sheets (**table 3a** to **table 3f**).

Table 2. Availability of information in the detail sheets for the defined processes

	Western and Central Europe	Nordic countries	Southern Europe	Eastern Europe
Integrated newsprint	X	X	---	---
Woodcontaining magazine paper	X	X	X	---
Woodfree fine paper	X	X	X	X
Containerboard	X	X	X	X
Cartonboard	X	X	X	---
Market pulp	X	X	X	X

The data sheets give information about the used raw material, production capacity and product. Social information as specific number of employees is added.

Regarding the sustainability indicators, the regions are compared by
- Water and energy management
- Effluent treatment and use of sludge
- Emissions to water
- Emissions to air

For the data collected in the detail sheets, some assumptions had to be made due to non-availability of several requested information: Specific energy consumption both in paper manufacturing and pulping for market pulp is always given for the whole process, including stock preparation or wood yard operations respectively.

Environmental and sustainability data are based on EMAS (Eco-Management and Audit Scheme) reports from selected mills in the respective regions. Although the emission figures in these reports cover a wide range, they were always below the given limits, which are different for the regions.

2.2 Production processes in the European regions

2.2.1 Integrated Newsprint

Integrated Newsprint production was regarded for two regions only – Western and Central Europe and Nordic countries. In Western and Central Europe, the integrated newsprint model mill uses 100% recovered paper as input. In the case of Nordic countries, pulp composition is 50% recovered paper (deinked pulp DIP) and 50% thermomechanical pulp (TMP). The production capacity in both regions is of comparable size. Differences are found in specific consumptions of energy and water – in Western and Central Europe is more water consumed than in Nordic countries, whereas the specific energy consumption is higher in the Nordic countries.

Newsprint is produced with somewhat higher number of employees in Western and Central Europe than in the Nordic countries.

2.2.2 Woodcontaining magazine paper

Woodcontaining magazine paper was not regarded for Eastern Europe. In Nordic countries, the pulp is composed from mechanical pulp (TMP) and from bleached softwood kraft pulp (BSKP), and the paper mill is run as integrated mill. In Western and Central Europe and in Southern Europe, the chemical pulp component in woodcontaining magazine paper is market pulp. Chemical pulp is always BSKP; mechanical pulp is pressure groundwood (PGW) in Southern Europe. In Western and Central Europe, mechanical fibres are delivered from recovered paper (DIP) to a certain extent. The ratio between chemical and mechanical fibres is roughly the same in all regarded regions. Production capacities are comparable in Western and Central Europe and in the Nordic countries. They are much smaller in Southern Europe, but specific consumption of energy and water is comparable for all regarded regions.

The number of employees is somewhat higher in Southern Europe.

2.2.3 Woodfree fine paper

Woodfree fine paper is produced in all European regions. It is made from a blend of bleached softwood kraft pulp (BSKP) and bleached hardwood kraft pulp (BHKP), the proportion in the furnish is similar for all regions. Only in Southern Europe the

tendency goes a bit more towards hardwood pulp. Fine paper is coated in Western and Central Europe, and the amount of fillers is thus higher than in other regions.

Higher production capacities are found in Western and Central Europe and in the Nordic countries, whereas it is much smaller in Southern Europe and in Eastern Europe, but these two regions have higher number of employees related on production.

2.2.4 Containerboard and Cartonboard

The production systems of container board and Cartonboard are rather similar; therefore they are discussed together and separated only for obvious differences.

Containerboard is produced in all European regions. The model mill behind containerboard is a kraftliner mill with two paper machines, one producing unbleached kraft liner, the other white top liner.

Containerboard is made from recycled corrugated containers (OCC) in all regarded regions except in Nordic countries, which use softwood kraft pulp, in some cases also hardwood kraft pulp in an integrated mill.

Almost ¾ of the total European production (about 70%) is made in the Nordic countries. The share of the other regions is about 20% for Western and Central Europe and about 5% each for Southern and Eastern Europe.

Independent on production capacity, the specific number of employees is comparable for all regions except Eastern Europe, where it exceeds the average value of the other region by the factor of 4.

Cartonboard is produced in all regions except Eastern Europe. In Western and Central Europe, it is made from a mixture of virgin and recovered fibres: unbleached kraft pulp (20%, softwood or hardwood), recycled paper and board (50%) and deinked pulp DIP (30%). In Southern Europe, only recovered fibres are used (85% recycled paper and board, 15% DIP). In Nordic countries, Cartonboard is made from virgin fibres only (55% kraft pulp, 45% pressure groundwood PGW).

The total production capacity of the regarded regions is divided as follows: Western and Central Europe 21%, Nordic countries 59%, and Southern Europe 20%.

The specific number of employees is comparably the same in Western and Central Europe and in Southern Europe. In Nordic countries, it is about 50% smaller than in the other regarded regions.

2.2.5 Market pulp (bleached chemical pulp)

Market pulp is produced in all European regions. Chemical pulp mills work as integrated mills in Nordic countries (softwood pulp) and in Southern Europe (hardwood pulp).

Raw material in Western and Central Europe and in Nordic countries is softwood. In Southern Europe and in Eastern Europe it is hardwood. For all regions, the relation between stem wood and wood chips is about 2:1.

The highest production capacity for market pulp to be used in woodfree fine paper is in Southern Europe (BHKP from eucalyptus). The production capacity in Eastern Europe is quite small (about 10% of the total European production capacity).

In integrated mills, a lower specific number of employees is found as seen for Nordic countries and Southern Europe, compared to the other regions. For selected market pulp mills in Western and Central Europe, the comparably low specific energy consumption was found.

Table 3a. Detail sheet Integrated Newsprint

Paper mill

Stock preparation

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Pulp type from integrated pulp mill	DIP	DIP, TMP	---	---
Pulp composition	100% DIP	50% DIP, 50% MP	---	---

Paper manufacturing

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Production capacity, kt/a	280	270	---	---
Basis weight, g/m²	45	45	---	---
Filler content /ash content, %	up to 15 (no fresh)	(<5 fresh, other from DIP)	---	---
Base paper coating	---	---	---	---
Fresh water consumption, m³/t	70	20	---	---
Specific energy consumption total, MWh/t	2.2	3.7	---	---

Information about sustainability indicators

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Carbon content of product, %	45	45	---	---

Social information

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Specific number of employees, capita/kt output	1.00	0.81	---	---

Recovery and integrated energy and steam production, water circuits

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Purchased electricity, MWh/t output	0.72	2.78	---	---
Purchased fuel, GJ/t output	5.72	1.22	---	---
Own electricity produces, % of needed power	24	3	---	---
Used fuels, %				
- Natural gas	72	7	---	---
- Biomass	15	80	---	---
- Coal	9	0	---	---
- HF oil	4	9	---	---
- Peat	0	4	---	---
Effluent treatment type	Dissolved air flotation	Dissolved air flotation	---	---
Use of sludge	Incineration, material recovery, landfill	Incineration, material recovery, landfill	---	---
Emissions to water				
- Chemical oxygen demand (COD), kg/t	2.2 – 2.9	9.0	---	---
- Biochemical oxygen demand (BOD_5), kg a.d./t	0.2 – 0.9	n/a	---	---
- Nitrogen (N), kg a.d./t	0.02 – 0.04	0.228	---	---
- Phosphor (P), kg/t	0.006	0.005	---	---
- AOX, kg/t	< 0.002	0.013	---	---
- Total suspended particulate matter (TSP), kg/t	0.37	0.5 – 1.0		
Emissions to air				
- Carbon dioxide (CO_2, fossil)), kg/ Adt	280 – 540	13.48	---	---
- Nitrogen oxides (NOx), kg NO_2 a.d./t	0.5 – 1.0	0.27	---	---
- Sulfur oxides (SOx), kg S a.d./t	< 0.005	0.33	---	---
- Particulates (dust), kg/t	< 0.004	0.02	---	---

Table 3b. Detail sheet Woodcontaining magazine paper

Paper mill

Stock preparation

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Integrated pulp mill	NO	YES	NO	---
Pulp type from integrated pulp mill	---	BSKP	---	---
Market pulp type	BSKP	---	BSKP	---
Mechanical pulp type/source	PGW/DIP	TMP	PGW	---
Pulp composition	10% DIP, 33% BSKP, 55% MP	35% BSKP, 65% MP	40% BSKP, 60% MP	---

Paper manufacturing

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Production capacity, kt/a	290	310	50	---
Basis weight, g/m²	39 (LWC)	52 (SC)	43 (MWC)	---
Filler content /ash content including coating layer, %	35	35	35	---
Base paper coating	YES	YES	YES	---
Specific fresh water consumption, m³/t	10 - 20	15 - 60	15	---
Specific energy consumption total, MWh/t	3.0 - 5.0	4.0 – 6.0	5.0	---

Information about sustainability indicators

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Carbon content of product, %	32.5	32.5	32.5	---

Social information

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Specific number of employees, capita/kt output	0.96	0.88	1.71	---

Recovery and integrated energy and steam production, water circuits

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Purchased electricity, MWh/t output	1.35	1.95	0	---
Purchased fuel, GJ/t output	5.00	5.17	12.27	---
Own electricity produces, % of needed power	0	11	99.9	---
Effluent treatment type	Activated sludge plant	Activated sludge plant		---
Use of sludge	External recovery, minor landfill	Incineration	External recovery, landfill	---
Used fuels, %				
- Natural gas	72	7	59	---
- Biomass	15	80	31	---
- Coal	9	0	0	---
- HF oil	4	9	10	---
- Peat	0	4	0	---
Emissions to water				
- Chemical oxygen demand (COD), kg/t	2.4 - 7	4 - 10	0.8	---
- Biochemical oxygen demand (BOD), kg/t	0.07 – 0.15	0.3 – 1.5	n/a	---
- Nitrogen (N), kg/t	0.01 – 0.1	0.03 – 0.25	0.1	---
- Phosphor (P), kg/t	< 0.015	< 0.01	0.003	---
- AOX, kg/t	0.007	0.09	n/a	---
- Total suspended particulate matter (TSP), kg/t	0.7	0.2 – 1.1	0.02 – 0.3	---
Emissions to air				
- Carbon dioxide (CO_2, fossil)), kg/ Adt	30 - 90	60 - 120	600 – 800	---
- Nitrogen oxides (NOx), kg NO_2 a.d./t	0.3	0.3 – 1.4	0.4 – 5	---
- Sulfur oxides (SOx), kg S a.d./t	0.004 – 0.1	0.2	< 0.006	---
- Particulates (dust), kg/t	0.009	0.3	< 0.006	---

Table 3c Detail sheet Wood-free fine paper

Paper mill

Stock preparation

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Integrated pulp mill	NO	YES	YES	NO
Pulp type from integrated pulp mill	---	BSKP, BHKP	BHKP	---
Market pulp type	BSKP, BHKP	---	BSKP	BSKP, BHKP
Mechanical pulp type	---	---	---	---
Pulp composition	33% BSKP, 67% BHKP	33% BSKP, 67% BHKP	25% BSKP, 75% BHKP	33% BSKP, 67% BHKP

Paper manufacturing

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Production capacity, kt/a	110	185	25	10
Basis weight, g/m²	78 (CWF)	77 (UWF)	77 (UWF)	77 (UWF)
Filler content /ash content including coating layer, %	45	20	20	20
Base paper coating	YES	NO	NO	NO
Specific fresh water consumption, m³/t	25 - 60	15 - 20	24	12 - 46
Specific energy consumption total, MWh/t output	3.2 – 5.7	1.7 – 2.3	2.5	7.2 – 10.5

Information about sustainability indicators

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Carbon content of product, %	27.5	40	40	40

Social information

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Specific number of employees, capita/t output	1.66	1.04	2.17	3.75

Recovery and integrated energy and steam production, water circuits

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Purchased electricity, MWh/t output	0.13	0.40	0.49	0.25
Purchased fuel, GJ/t output	7.99	4.20	5.44	12.13
Own electricity produces, % of needed power	81	60	49.6	95
Composition of used fuels, %				
- Natural gas	72	7	59	15
- Biomass	15	80	31	47
- Coal	9	0	0	34
- HF oil	4	9	10	4
- Peat	0	4	0	0
Effluent treatment type	Activated sludge plant	Activated sludge plant	Activated sludge plant	Physical, biological treatment
Use of sludge	External recovery	Incineration	Incineration	External recovery
Emissions to water				
- Chemical oxygen demand (COD), kg/t	8 - 16	0.8 - 2	0.8	0.7 – 8.0
- Biochemical oxygen demand (BOD), kg/t	0.5	0.2 – 0.8	0.3	0.15
- Nitrogen (N), kg/t	0.2	0.03	0.03	0.05
- Phosphor (P), kg/t	0.02	0.003	0.01	0.003
- AOX, kg/t	0.001	n/a	n/a	0.03
- Total suspended particulate matter (TSP), kg/t	0.4 – 1.0	0.2 – 0.4	0.34	0.12
Emissions to air				
- Carbon dioxide (CO_2, fossil)), kg/ Adt	500 – 1000	50	550	240 – 880
- Nitrogen oxides (NOx), kg NO_2 a.d./t	0.8 – 2.0	0.03	0.63	1.4
- Sulfur oxides (SOx), kg S a.d./t	0.6 – 1.0	0.08	0.03	5.1
- Particulates (dust), kg/t	0.03 – 0.09	n/a	0.004	0.1 – 4.0

Table 3d Detail sheet Containerboard

Board mill

Stock preparation

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Integrated pulp mill	NO	YES	NO	NO
Pulp type from integrated pulp mill	---	SKP (some HKP)	---	---
Market pulp type	Recycled paper and board	---	Recycled paper and board	Recycled paper and board
Mechanical pulp type/source	---	---	---	---
Pulp composition	100% RP	100% KP	100% RP	100% RP

Paper manufacturing

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Production capacity, kt/a	75	290	20	20
- Testliner	YES	YES	YES	YES
- Fluting	YES	YES	YES	YES
Basis weight, g/m²	145	100-190	150	150
Filler content /ash content including coating layer, %	NO	NO	NO	NO
Base paper coating	---	---	---	---
Specific fresh water consumption, m³/t	5	40	5	5
Specific energy consumption total, MWh/t	3.5	3.6	3.5	3.5

Information about sustainability indicators

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Carbon content of product, %	50	50	50	50

Social information

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Specific number of employees, capita/kt output	0.81	0.94	0.93	4.00

Recovery and integrated energy and steam production, water circuits

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Purchased electricity, MWh/t output	0.31	0.48	0.26	0.26
Purchased fuel, GJ/t output	8.45	3.16	9.56	11.39
Own electricity produces, % of needed power	39	50	51.3	55
Used fuels, %				
- Natural gas	72	7	59	15
- Biomass	15	80	31	47
- Coal	9	0	0	34
- HF oil	4	9	10	4
- Peat	0	4	0	0
Effluent treatment type	Physical, biological	Physical, biological	Physical, biological	Physical, biological
Use of sludge	External recovery, minor landfill	External recovery, minor landfill	External recovery, landfill	External recovery, landfill
Emissions to water				
- Chemical oxygen demand (COD), kg/t	0.8	7 – 15	0.4 – 0.9	2 – 20
- Biochemical oxygen demand (BOD), kg/t	0.05 – 0.13	1.4 – 7.0	0.03 – 0.15	n/a
- Nitrogen (N), kg/t	0.03	0.05 – 0.3	0.03	n/a
- Phosphor (P), kg/t	0.005	0.01 – 0.04	0.004 – 0.008	n/a
- AOX, kg/t	0.0007	0.002	n/a	n/a
- Total suspended particulate matter (TSP), kg/t	< 0.2	2.4 – 3.6	0.08 – 0.17	0.1 – 0.8
Emissions to air				
- Carbon dioxide (CO_2, fossil)), kg/ Adt	360	80 – 150	250	470
- Nitrogen oxides (NOx), kg NO_2 a.d./t	0.4 – 1.1	0.9 – 1.4	0.08 – 0.14	0.1 – 0.7
- Sulfur oxides (SOx), kg S a.d./t	0.02 – 0.05	0.2 – 0.5	< 0.006	0.003
- Particulates (dust), kg/t	0.004	0.1 – 0.8	n/a	n/a

Table 3e Detail sheet Cartonboard

Board mill

Stock preparation

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Integrated pulp mill	NO	YES	NO	---
Pulp type from integrated pulp mill	---	~40%SKP, 60% HKP	---	---
Market pulp type	~40%SKP, 60% HKP, recycled paper and board	---	Recycled paper and board	---
Mechanical pulp type/source	---	PGW	---	---
Pulp composition	50% RP, 30% DIP, 20% KP	55% KP, 45% MP	85% RP, 15% DIP	---

Paper manufacturing

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Production capacity, kt/a	65	180	60	---
Basis weight, g/m²	215	215	215	---
Filler content /ash content including coating layer, %	0 (typically)---	5-12 (top-ply)---	0 (typically)	---
Base paper coating	---	---	---	---
Specific fresh water consumption, m³/t	100	50 – 90	100	---
Specific energy consumption total, MWh/t	6.0	4.5 – 5.0	6.0	---

Information about sustainability indicators

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Carbon content of product, %	50	50	50	---

Social information

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Specific number of employees, capita/kt output	1.60	0.87	1.75	---

Recovery and integrated energy and steam production, water circuits

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Purchased electricity, MWh/t output	0.38	0.01	0.76	---
Purchased fuel, GJ/t output	10.44	10.89	13.02	---
Own electricity produces, % of needed power	71	99.5	48.2	---
Used fuels, %				
- Natural gas	72	7	59	---
- Biomass	15	80	31	---
- Coal	9	0	0	---
- HF oil	4	9	10	---
- Peat	0	4	0	---
Effluent treatment type		Aerated lagoon		---
Use of sludge		Incineration /material recycling		---
Emissions to water				
- Chemical oxygen demand (COD), kg/t	2.11	0.2 – 15	11	---
- Biochemical oxygen demand (BOD), kg/t	0.13	n/a	n/a	---
- Nitrogen (N), kg/t	0.04	0.06 – 0.3	n/a	---
- Phosphor (P), kg/t	0.005	0.002 – 0.04	n/a	---
- AOX, kg/t	0.002	n/a	n/a	---
- Total suspended particulate matter (TSP), kg/t	0.25	0.2 – 3.7	0.91	---
Emissions to air				
- Carbon dioxide (CO_2, fossil)), kg/ Adt	260 – 780	320	1266	---
- Nitrogen oxides (NOx), kg NO_2 a.d./t	n/a	0.002 – 1.8	n/a	---
- Sulfur oxides (SOx), kg S a.d./t	n/a	0.002 – 0.45	n/a	---
- Particulates (dust), kg/t	n/a	0.36	n/a	---

Table 3f Detail sheet Market pulp

Pulp mill

Wood yard

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Integrated pulp mill	NO	YES	YES (BHKP)	NO
Type of raw wood (stem wood or chips)	70% stem wood, 30% chips	70% stem wood, 30% chips	70% stem wood, 30% chips	70% stem wood, 30% chips
Kind of wood	Softwood	Softwood	Hardwood	Hardwood

Pulp manufacturing

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Market pulp type for woodfree fine paper	BSKP	BSKP	BHKP	BHKP
Production capacity, kt/a	135	190	205	65
Bleaching process	ECF	ECF	ECF	ECF
Yield	50%	50%	50%	50%
ISO brightness	89	89	89	89
Specific fresh water consumption total, m^3/t	27	60 – 75	30 – 50	49
Specific energy consumption total, MWh/t output	1.5	6 - 7	5 - 7.5	n/a

Information about sustainability indicators

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Carbon content of product, %	50	50	50	50

Social information

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Specific number of employees, capita/t output	4.29	1.14	1.00	5.70

Recovery and integrated energy and steam production, water circuits

	W Central Europe	Nordic countries	Southern Europe	Eastern Europe
Purchased electricity, MWh/t output	0.13	0.09	0.36	0.34
Purchased fuel, GJ/t output	0.68	-1.75	7.07	9.90
Own electricity produces, % of needed power	85	88	70	63
Composition of used fuels, %				
- Natural gas	72	7	59	15
- Biomass	15	80	31	47
- Coal	9	0	0	34
- HF oil	4	9	10	4
- Peat	0	4	0	0
Effluent treatment type	Activated sludge plant	Activated sludge plant	Activated sludge plant	Activated sludge plant
Use of sludge (e.g. incineration, landfill etc.)	Incineration	Incineration	Incineration recovery landfill	Landfill, recovery incineration
Emissions to water				
- Chemical oxygen demand (COD), kg/t	6 – 40	5 – 20	7 - 17	8
- Biochemical oxygen demand (BOD), kg/t	0.1 – 2.0	0.3	1.6 – 8.4	n/a
- Nitrogen (N), kg/t	n/a	0.1	0.17	n/a
- Phosphor (P), kg/t	n/a	0.008	0.01 – 0.08	n/a
- AOX, kg/t	0.25 – 0.45	0.15	0.2	0.09
- Total suspended particulate matter (TSP), kg/t	0.4 – 5.0	0.28	1.12 – 3.32	n/a
Emissions to air				
- Carbon dioxide (CO_2, fossil)), kg/ Adt	n/a	135 - 147	230 – 270	590
- Nitrogen oxides (NOx), kg NO_2 a.d./t	1.7	1.7	1.2	1.1
- Sulfur oxides (SOx), kg S a.d./t	0.002 – 0.04	n/a	n/a	3.2
- Particulates (dust), kg/t	0.04 – 0.13	0.14	n/a	0.21

2.3 Sustainability indicators in European regions

2.3.1 Energy management

The proportion of used fuels in the regarded regions is not divided by paper grades. The overview makes obvious, that in Nordic countries almost all fuel is made from biomass (80%), whereas in Western and central Europe and Southern Europe 70% and 50% respectively are made from natural gas. Biomass in these regions is used with 15% and 30% respectively.

The situation is totally different in Eastern Europe where 34% of fuel is still made from coal, which results in high fossil carbon dioxide emissions as well as in high particulate (dust) proportions.

Peat as fuel is used to a very low extend only in Nordic countries.

Integrated newsprint

In Western and Central Europe, purchased energy is focused on fuel, with highest proportion in natural gas followed by biomass. In the Nordic countries, more electricity is purchased. The production of TMP is the most electricity demanding part of the production process, whereas steam demand is highest in the drying section.

Woodcontaining magazine paper

The main input of energy to the paper machine is steam for drying of the paper. The efficiency of the paper machine (need for re-drying of broke) and the dryness of the paper after the press section are of big importance for the steam consumption of the paper machine.

In Central and Western Europe, no own electricity is produced, and the purchased fuel is mainly natural gas. The mills in Southern Europe produce almost all required energy as electricity internally, purchased fuel is mainly natural gas followed by biomass. No electricity is purchased. In the Nordic countries, a small proportion of the required energy is produced internally as electricity. Purchased energy is electricity and fuel (biomass, e.g. bark).

Woodfree fine paper

The main input of energy to the paper machine is steam for drying of the paper. Most of the power consumption takes place in motors for pumps, screens, drives and refiners in the paper mill. Most of this energy is going into the process flow as thermal energy and contribute to keep the system temperature on a high level. A high level improves the dewatering on the wet end and minimises bacteriological and slime problems.

The steam production in the recovery boiler of an integrated fine paper mill is not enough to meet the steam demand. The required additional steam is produced by burning of bark. A fine paper mill is self-sufficient in steam consumption, whereas 30 - 50% of the consumed electric energy has to be purchased. In non-integrated mills, almost all required electricity comes from own production, the purchased energy is mainly from fuel.

Containerboard and Cartonboard

The main input of heat energy to the paper machine is steam for drying of the paper out from the press section. The dryness of the paper after the press section and the efficiency of the paper machine (need for re-drying of broke) are the main factors affecting the steam consumption in the paper machine.

The main of the power consumption takes place in motors for the drives, pumps, screens and refiners in the paper mill.

The recovery system in an integrated containerboard mill is based on the recovery system of a kraft pulp mill, which recovers the inorganic pulping chemicals, produces process heat and electric power and recovers organic by-products like tall oil. The integrated kraft pulp mills are normally self-sufficient in heat and electric power and thus contribute to lower amount of purchased electricity or fuel.

For *Containerboard*, the specific energy consumption is almost the same in all regions. For *Cartonboard*, it is obviously lower in the Nordic countries with integrated mills.

In the integrated mills for *containerboard* production, the steam production in the recovery boiler is not enough to meet the steam demand in the integrated kraftliner mill. A portion of the bark is gasified and utilised as fuel in the lime kiln; the rest is burned in the power boiler to produce the required additional steam. This decreases the total value of purchased fuel especially for Nordic countries compared to the other regions.

In an integrated *Cartonboard* mill (Nordic countries), the total electricity is from own production.

Market pulp

The recovery system in a kraft pulp mill recovers the inorganic pulping chemicals, produces process heat and electric power and recovers organic by-products like tall oil. Kraft pulp mills are normally self-sufficient in heat and electric power.

In Western and Central Europe and in Nordic countries, very little electricity and fuel is purchased. In Nordic countries, fuel as biomass (bark) is even sold (negative figure of purchased fuel in **table 3f**, p. 17). The pulp mills in Southern Europe and in Eastern Europe require a bit more energy, the own electricity produced covers only 70% or 63% respectively of the needed power.

Only little information is available about specific energy consumption. The figures shown in **table 3f** give an impression but cannot be utilized for a representative description of energy usage in the regarded regions.

2.3.2 Water management

Integrated newsprint

In order to control the loads of unwanted substances in the process water and to maintain the fines and ashes at a controllable level in the process water loops, internal cleaning of the water circuits is carried out by dissolved air flotation (DAF).

Woodcontaining magazine paper

Almost all dissolved substances in the integrated mill system is coming from the TMP process and bleaching process. To make the paper machine system as clean as possible and to achieve good bleaching conditions it is important to have a series of dewatering and dilution stages with counter current white water flow between paper machine, bleach plant and TMP-mill. Practically, this means fresh water is added on the paper machine and contaminated excess white water is withdrawn from the TMP-mill and bleach plant.

The warm water system is the main fresh water consumer in the paper mill. Warm water is mainly used for high pressure cleaning showers in the wire- and press sections and for dilution of different chemicals.

Specific water consumption is of the same level in all regarded regions with a wider range in the Nordic countries.

Woodfree fine paper

The mill is designed with a very low process water consumption. There is also a consumption of water for cooling purposes in the mill. Almost all cooling is made with a closed cooling system.

The warm water system is the main fresh water consumer in the paper mill. In integrated mills, warm water is received from the kraft mill.

Specific water consumption covers a wider range and is lower for integrated mills (Nordic countries and Southern Europe) than for non-integrated mills.

Containerboard and Cartonboard

The white water flow is counter-current from the liner machine to the recycled fibre line (RCF). Normally rejects are the only contaminated streams out from the paper machine.

The only fresh water to the recycled fibre line is sealing water.

Specific water consumption depends on the integration of the pulp production, especially for *Containerboard*. The non-integrated board mills in Western and Central Europe and in Southern Europe can work with rather low specific water consumption. For *Cartonboard*, the integrated mill in the Nordic countries specific water consumption is somewhat lower than for the other regarded regions.

Market pulp

Market pulp is produced in closed systems with environmentally friendly technologies, always to apply the lowest possible amount of water. Such technologies reduce the use of fresh water as well as total waste water volume.

As already mentioned above, only little information is available about specific consumptions. The figures shown in **table 3f** give an impression but cannot be utilized for a representative description of fresh water usage in the regarded regions. However, the few values found are in the same range for all regarded regions.

2.3.3 Effluent treatment and use of sludge

Integrated newsprint

Rejects of various types and sludges are generated during different cleaning steps, due to contamination of the feedstock (recovered paper). Core system in the effluent treatment is dissolved air flotation (DAF).

Sometimes rejects can be used e.g. as a fuel or as a raw material for other products, which are new purposes. In such cases it should be considered a by-product and not a waste. Generally said, the treatment of the effluents and use of resulting sludge is the same both in Western and Central Europe and in the Nordic countries.

Woodcontaining magazine paper

Effluent treatment comprises pre-treatment (cooling equipment and neutralisation), primary treatment and biological treatment. The effluent is treated in a biofilm reactor with suspended carriers followed by an activated sludge plant, which comprises aeration basin and secondary clarifier.

In Western and Central Europe and in Southern Europe, where the mills are not integrated, sludge is recovered externally, e.g. for fibre reuse in fluting mill or in the brick industry. A small part is used for landfill, which is of minor importance in Western and Central Europe than in Southern Europe. The integrated mills in the Nordic countries support sludge incineration.

Woodfree fine paper

Waste water from the process is treated in an activated sludge plant with additional nitrogen to feed the bacteria in the biosludge. In non-integrated mills, the sludge is externally recovered. The integrated mills support sludge incineration.

Containerboard and Cartonboard

The only chemicals that are required in the RCF plant are flocculation chemicals for the dissolved air flotation (DAF) and the sludge dewatering. Polymers are dissolved in fresh water and added to the water to be treated in the DAF.

The filtrate from the reject handling and the screw press is treated in a dissolved air flotation unit (DAF). This treatment reduces the fines and ash content in the pulp as the screw press washes these out. The effluent from the RCF plant is the treated water from the DAF unit.

Several treatment types for the final mill effluents are applied. *Containerboard* mills have different physical and biological treatments. For *Cartonboard* mills, aerated lagoon is a common treatment process.

In integrated mills, biological sludge will be incinerated in the bark boiler. In the other cases, it goes to external recovery and partly to landfill.

Market pulp

Final waste water from the process is treated in an activated sludge plant with additional nitrogen to feed the bacteria in the biosludge. The effluent treatment is the same as described for the woodfree fine paper mill.

In Western and Central Europe and in Nordic countries, the sludges goes to incineration. In Southern Europe, also external recovery and landfill (of minor importance) is possible.

In Eastern countries, a great part of the sludge goes to landfill, other parts are externally recovered or used in own power production by incineration.

2.3.4 Emissions to water

Integrated newsprint

The absence of a chemical recovery system in mechanical pulping means that all substances, which are dissolved in the process during pulping will be found in the waste water from the process. This is resulting in a higher COD value in the Nordic countries. Also N, AOX and suspended solids (TSP) levels are higher.

Woodcontaining magazine paper

The emissions to water are based on the same process impact as described for integrated newsprint. The integrated mills in the Nordic countries cause a higher COD level compared to Western and Central Europe and to Southern Europe. Also the other emissions – BOD, N, P, AOX and TSP are higher in the Nordic countries compared with the other regarded regions.

Woodfree fine paper

The COD values are quite similar for the integrated mills in Nordic countries and Southern Europe. Within the integrated mills, the greatest difference was found for the emission of phosphorous compounds (P). Non-integrated mills in Western and Central Europe have not only a higher proportion of nitrogen compounds (N), but also a higher proportion of total suspended particulate matters (TSP).

Containerboard and Cartonboard

The amount of COD dissolved is very much dependent on the raw material for the recycled fibre. Wide ranges of COD values are found, also in the Nordic countries where no recycled fibres are used. Additionally, fewer emission data are available for board production than for paper production especially from Eastern Europe. That's why a sufficient differentiation between the regarded regions is not possible.

The emissions to water in *Containerboard* manufacturing are similar for Western and Central Europe and for Southern Europe. Some similarities are also found for Western and Central Europe and for Nordic countries in *Cartonboard* manufacturing.

Market pulp

As main indicators for emissions to water, pulp mills use COD, AOX and total suspended particulate matter (TSP).

COD covers a wide range, but the lowest reported values are the same in all regarded regions. AOX is in comparable levels for Western and Central Europe, Nordic countries and Southern countries. Rather low value was found for Eastern Europe but this might not be representative. TSP is lowest for Nordic countries and highest for Southern Europe (Eastern Europe not available).

2.3.5 Emissions to air

Integrated newsprint

The higher level of fuel application in Western and Central Europe is leading to a much higher level of CO2-emission to the air, but the proportion of sulphur compounds and of dust is much lower.

Woodcontaining magazine paper

The specific fossil carbon dioxide emission shows great differences between the regions. The lowest values are found for Western and Central Europe. Also the other emission - NOx, SO2 and particulates (dust) - are obviously lower than e.g. in Nordic countries. The highest carbon dioxide emission was found for Southern Europe.

Woodfree fine paper

Similar differences as for emissions to water were also found for emission to air - lower emission values for the integrated mills in Nordic countries and Southern Europe than for the non-integrated mills in the other regions. The high proportion of biomass in the used fuels causes a lower value in emitted fossil carbon dioxide for the Nordic countries. The high value for particulates (dust) in Eastern Europe is related to the high proportion of coal in the used fuels.

Containerboard and Cartonboard

Fossil carbon dioxide emissions are a bit lower for *Containerboard* production in Nordic countries compared to the other regions and also compared to *Cartonboard*. An extremely high value was found for *Cartonboard* in Southern Europe. However, this value might not be representative enough for the total region due to low availability of emission data.

Particulates (dust) were found to be highest portion in Nordic countries both for *Containerboard* and for *Cartonboard*.

Market pulp

Fossil carbon dioxide emissions are the highest in Eastern Europe. Due to use of coal, also a high value for particulates (dust) is found. NOx compounds are of the same level for all regions. As result of the policy of low emission limits for sulphur compounds (FGD), very low amount of sulphur oxides are found for Western and Central Europe.

3 The Solid Wood value chain

3.1 Data collection and detail sheets

The industrial processes in the solid wood value chain were described in great detail based on model mill concepts in report PD 4.1.7.

Raw material for the processes in the solid wood chain is mainly softwood. For the region of Eastern Europe, also hardwood is included concerning sawmills and particle board mills.

For the solid wood value chain, detail information was collected for 6 different processes as far as available (**table 4)** and are assembled in the so-called detail sheets (**table 5a-f**).The solid wood processes are very different, that's why also the information in the data sheets are different, and not all data are available for all processes. However, the data are related to proportion of products related on wood input, and specific consumption of energy and water.

Environmental and sustainability data are added to the detail sheet of sawmilling only (**table 5a**). Because there are more than only one single products produced in the solid wood industry, it is difficult to get specific data for one single product. Environmental and sustainability data are based on EMAS (Eco-Management and Audit Scheme) reports from selected mills in the respective regions. Although the reported emission figures cover a wide range, they were always below the given limits, which are different for the regions.

Social information as specific number of employees is added.

Table 4. Availability of information in the detail sheets for the defined processes in the solid wood chain

	Central and Southern Europe	Nordic countries	Eastern Europe
Sawmill	X	X	X
Panel products (Particle board)	X	X	X
Panel products (Plywood)	---	X	X
Building components (Roof truss)	X	X	---
Joinery (windows)	X	X	---
Wooden houses	---	X	---

Table 5a. Detail sheet Sawmill

	Central and Southern Europe	Nordic countries	Eastern Europe	
Type of wood	Softwood	Softwood	Softwood	Hardwood
Proportion of input utilized as (%)				
- Bark	0 – 10	10	9 – 11	7 – 8
- Chips	20 – 30	30	24 – 34	10 – 22
- Sawdust	15 – 25	12	4 – 12	7 – 9
- Rejects	3 – 6	1	2 – 5	4 – 6
- Sold undried	15 – 20	2	30 – 35	30 – 35
- Sold dried	30 – 40	45	30 – 35	30 – 35
Specific energy consumption total, kWh/m³	194	400	200	220
Specific electricity usage, kWh	16.6	65	40	41
Specific consumption (wood chips), kWh/m³	177		175	180
Specific energy breakdown, %				
- Debarking	5 – 15	6	10	10
- Chipping	5 – 15		10	10
- Processing	30 – 40	18	35	35
- Drying	40 – 50	76	45	45
Specific water consumption total, L/m³	50 – 250	50	90	

Social information

	Central and Southern Europe	Nordic countries	Eastern Europe
Number of employees, capita/1000 m³	0.6	0.42 – 1.08	0.34 – 1.4

Emissions to water

	Central and Southern Europe	Nordic countries	Eastern Europe
Chemical oxygen demand (COD)	40 – 270 mg/L	0.9 kg/m³	
Biochemical oxygen demand (BOD)	7 – 50 mg/L	2 – 50 g/m³	10 – 84 kg/m³
Nitrogen (N, from ammonium)	0.02 – 20 mg/L		
Phosphor (P)		0.06 – 6.5 g/m³	
Hydrocarbons total	0.2 mg/L		
Total suspended particulate matter (TSP)		2 – 350 g/m³	84 kg/m³

Emissions to air

	Central and Southern Europe	Nordic countries	Eastern Europe
Carbon dioxide , kg/m³			
- CO_2 (fossil)	4.5 – 9.5		
- CO_2 (diesel)	4.5 – 9.5		0.9
Carbon monoxide (CO), g/m³			0.68
Nitrogen oxides (NOx), g/m³		68 – 111	0.62
Sulfur oxides (SOx), mg/m³			46
Particulates (dust), g/m³		30 – 80	0.5
Volatile organic compounds (VOCs), mg/m³			7.5

Table 5b. Detail sheet Particle board mill

	Central and Southern Europe	Nordic countries	Eastern Europe	
Type of wood chips	Softwood	Softwood	Softwood	Hardwood
Source of wood chips, %				
- Imported	75 – 85	100	10 – 20	10 – 20
- Produced on-site	15 – 25	0	80 – 90	80 – 90
Specific energy consumption total, kWh/m³	208	960	200	210
Specific electricity usage, kWh/m³	104	180	110	115
Specific natural gas usage, kWh/m³	43	0		
Specific energy breakdown, %				
- Drying	20 – 30	75	25	25
- Gluing	2.5 – 7.5	1	5	5
- Pressing	40 – 45	10	50	50
- Machining	2.5 – 7.5	14	5	5
- Associated machinery & kit	10 – 20		15	15
Specific water consumption total, L/m³	304	0	350	350
Proportion of raw material utilized, %	92.5 – 97.5	99	95	95
Proportion of rejects, %	2.5 – 7.5	1	5	5

Table 5c. Detail sheet Plywood production

	Central and Southern Europe	Nordic countries	Eastern Europe
Type of wood	Softwood	Softwood	---
Proportion of input utilized as (%)			
- Bark	---	11	7 – 12
- Veneers	---	39	70
- Peeler cores	---	22	20
- Rejects	---	28	10
Specific energy consumption total, kWh/m³	---	450	150 – 200
Specific energy breakdown, %			---
- Peeling	---	14	53
- Drying	---	69	2
- Gluing	---	2	1
- Pressing	---	12	43
- Trimming and sanding	---	3	1
Specific water consumption total, m³	---	0	15 – 24-
Proportion of raw material utilized, %	---	35	50 – 60
Proportion of rejects, %	---	65	

Table 5d. Detail sheet Roof truss production

	Central and Southern Europe	Nordic countries	Eastern Europe
Type of wood	Softwood	Softwood	---
Grade of timber required	C24/TR26		---
Proportion of raw material utilized, %	90 – 95	85	---
Proportion of off-cuts, %	7.5 – 12.5	5	---
Proportion of rejects, %	0 – 5	10	---
Specific energy consumption total, m³	30.8	70	---
Specific energy break-down, %			
- Machining	30 – 70	90	---
- Pressing	30 – 70	10	---
Specific water consumption, m³			---

Table 5e. Detail sheet Window production

	Central and Southern Europe	Nordic countries	Eastern Europe
Type of wood	Softwood	Softwood	---
Grade of timber required	not relevant		---
Proportion of raw material utilized, %	35 – 65	49	---
Proportion of rejects, %	10 – 30		---
Proportion of waste, %	25 – 35	51	---
Specific energy consumption total, m^3	30.8	67	---
Specific energy break-down, %			
- Machining	100		---
Specific water consumption, m^3	0		---

Table 5f. Detail sheet Wooden houses

	Central and Southern Europe	Nordic countries	Eastern Europe
Type of wood			
Proportion of input utilized as (%)			
- Wooden house components	---	92	---
- Sawdust	---	2	---
- Rejects	---	6	---
Specific energy consumption total, m^3	---	40	---
Specific energy breakdown, %			
- Processing	---	100	---
Specific water consumption total, m^3	---	---	---

3.2 Production processes in the European regions with respect to sustainable aspects

3.2.1 Saw milling

Phases in the saw mill converting wood stems to sawn timber are described in great detail in report PD 4.1.7. More than 50% of the products in a sawmill is sawn timber in Central and Southern Europe and in Eastern Europe. In Nordic countries, the proportion of this product is less than 50%. From the remaining proportions, only up to 6% is called “reject”, the other are by-products like wood chips, sawdust and bark, which can be utilized by other processes. Wood chips are sold to the pulp industry, sawdust and other mill waste is processed into particle board and related products. Bark is ground for soil improvement, or it may also be burned for heat. Sawdust is usable for particle board or can be pressed into wood pellets.

Differences between softwood and hardwood processing in Eastern Europe are found in the proportion of chips and sawdust compared to sold sawn timber (lower for hardwood), and in total specific energy consumption (somewhat higher for hardwood).

Specific number of employees covers a larger range but this is similar for all regions.

Energy management

Total specific energy consumption is of comparable level in Central and Southern Europe and in Eastern Europe. About the double amount is used in Nordic countries, where also a higher consumption of electricity is found.

The breakdown of the specific energy consumptions to single process parts is also different for the Nordic countries. No specific energy consumption is given for chipping, which covers 5 to 15% of the consumed energy in the other regions. In the Nordic countries, less energy is used for processing, but ¾ of the energy is used for drying processes.

Sawdust and/or bark are burned to produce thermal energy. About 70% of all produced energy is used for drying processes and other heating purposes in Central Europe, superfluous energy may be feed onto the grid. Thermal energy used for the sawmill in this region is therefore CO_2-neutral.

Water management

Fresh water is used for conditioning of the drying chambers, sprinklers and mill hydrants. Specific water consumption is in the same level for all regarded regions.

3.2.2 Panel products – Particle board

Phases in the production of particleboard are described in detail in report PD 4.1.7.

Particleboard is an engineered wood product manufactured from e.g. wood chips, sawmill shavings, or even saw dust, and a synthetic resin or other suitable binder, which is pressed and extruded. In many instances, the raw material is a mixture of all kinds.

In Central and Southern Europe, about ¼ of the required wood chips are produced on-site, whereas ¾ of the chips are imported. There is no difference between softwood and hardwood processing in Eastern Europe. Particleboard plants have a very high proportion of utilized raw material, which is the highest in Nordic countries (99%). The rejects are non-usable chips and sawdust, which were pressed to pellets as by-product.

Differences between softwood and hardwood processing in Eastern Europe are only found in total specific energy consumption and usage of electricity, which are slightly higher for hardwood than for softwood.

Energy management

Particleboard production is energy intensive. The energy plant utilizes waste from panel production to produce most of the energy required to run the plant. The plant can use any kind of fuel from bark and start-up fibre to sander dust and rejected particleboards. Also external low-grade fuel can be used such as sawmill chips and recycled wood materials unsuitable for production.

Great differences in specific energy consumption are found between Nordic countries and the other regarded regions. Much more energy is used in Nordic countries, and like for plywood production, this is mainly used in drying processes. In Central and Southern Europe and in Eastern Europe, more energy is used for pressing processes like in Nordic countries.

The energy plant can also supply heat to other process stages. Thermal oil for continuous press, steam for refiner system and heat for almost any other stage can be supplied.

Water management

Specific water consumption is not available for Nordic countries. In the other regarded regions, it is of comparable level.

3.2.3 Panel products – Plywood

Phases in the manufacturing process of plywood are described in detail in report PD 4.1.7. Detail information about plywood processes is available only for Nordic countries and Eastern Europe (**table 5c**).

Plywood production requires a good log, called a peeler, which is generally straighter and larger in diameter than one required for processing into dimensioned lumber by a sawmill. The log is peeled into sheets of veneer which are then cut to the desired dimensions, dried, patched, glued together and then baked in a press at 140 °C and

19MPa to form the plywood panel, which then can be patched, resized, sanded or otherwise refinished.

By products from this process line are bark, which will be refined and used for energy, saw dust, which will be mixed with bark, and rejected blocks, which are cut and chipped and used for fibreboard.

Regarding the proportion of utilized products and by-products, the proportion of bark and peeler cores is similar for both regarded regions. In Eastern Europe, much more veneer is produced than in Nordic countries, and thus the reject proportion is higher in the Nordic countries than in Eastern Europe. In Eastern Europe, the total proportion of utilized raw material is up to twice as much as in Nordic countries.

Energy management

Also plywood manufacturing is an energy-intensive process due to drying and pressing – practically this is performed in a heated press, which is heated by hot oil.

Specific energy consumption is – like for sawmilling – about the double in Nordic countries compared to Eastern Europe. The highest proportion in the energy breakdown is used for drying purposes in the Nordic countries. In Eastern Europe, more energy is used for peeling and pressing.

Water management

Debarked blocks are conditioned in chambers with hot water sprays before fed in to the mill. The water is mainly heated with dryer exhaust air through a scrubber and partly with steam through a heat exchanger. Conditioning temperature is abt. 50-70 °C. The water is mechanically filtered and its pH is controlled with NaOH.

Wastewater discharge from the production line is solved by a separate sewage system.

3.2.4 Building components – Roof truss

Production principles of roof truss manufacturing are shown in detail in report PD 4.1.7. The process is close connected to gluelam manufacturing, which is described detailed in report PD 4.1.7, too. Detail information is available for Central and Southern Europe and for Nordic countries only (**table 5d**).

Roof truss is a precast constructional element made from sawn timber, or from gluelam. Special information about the grade of timer required was available only for Central and Southern Europe. At least 85% of the raw material is utilized for the product, with a higher proportion in Central and Southern Europe than in Nordic countries. Rejects are wood chips from the planing and finger-jointing processes and sawdust from planing machines, which were pressed to pellets as by-product.

Energy management

In Nordic countries, more than twice as much energy is used than in Central and Southern Europe. In Central and Southern Europe, there is an even distribution of the specific energy between the two process areas machining and pressing. In Nordic countries, almost all energy is consumed for machining. Like already in the earlier described processes from sawmill to panel production, in Nordic countries in general less energy is used for pressing processes compared to other regarded regions.

Water management
No detail information was available for specific water consumption and water use.

3.2.5 Joinery – Window production

The manufacturing process of wooden windows is described in detail in report PD 4.1.7. Detail information is available for Central and Southern Europe and for Nordic countries only (**table 5e**).

Raw material is either finger-jointed solid wood components or finger-jointed laminated components. Wooden window factories are large assembly plants with all materials coming as ready as possible just to get assembled. From the delivered wooden raw material, between 35% and 65% are utilized in Central and Southern Europe. For Nordic countries, this figure is given with about 50% and thus just within the range of the other regarded region. In Central and Southern Europe, about one third of the raw material is defined as reject with will be further processes to pellets. No rejects like this are defined for Nordic countries, where the not utilized material is declared as waste.

The paints used are weatherproof, water-borne and polyurethane paints. Alternatively, the woodwork can be painted with special tints. In addition, the backside of the frame has been primed.
Energy management
No distinction has been made for specific energy consumption within the process steps. As already in the other cases, specific energy consumption in Nordic countries is about twice as much compared to the other regarded region.

Water management
No detail information was available for specific water consumption and water use.

3.2.6 Wooden houses

Phases in the wooden house assembly are shown in detail in report PD 4.1.7. The product “wooden house” is an assembly from different material like sawn and further processed timer, plywood, and gluelam, which were described and discussed already above. Detail information is available only for Nordic countries; therefore a comparison between the European regions is not possible (**table 5f**).

3.3 Considerations about sustainability indicators in European regions

Information about sustainable indicators like emission data are more difficult to get than in the Fibre value chain. Public reporting of this information is more in use in the pulp, paper and paperboard industry than in the Solid wood industry. Available data are related to sawmills, they are added to **table 5a**.

3.3.1 Emissions to air

Emissions to air are of greater importance in the Solid wood chain than emissions to water. Carbon dioxide from diesel fuel and volatile organic compounds are the most interesting indicators.

The consumption of carbon dioxide CO_2 (diesel) is related to the transport operations within and outside the plants. Specific emissions to air are very different between Central and Southern Europe and Eastern Europe, where high effort is made to decrease this emission by using electric vehicles for on-site transports.

The emission of volatile organic compounds (VOC), also called organic gas, is of greater interest in the panel production (plywood and particleboard). But only few data are available about VOC emissions. There is a tendency that VOC is slightly higher when more bark is used as raw material.

3.3.2 Emissions to water

Emissions to water can only be compared when the solid wood plant has an own sewage treatment. In most cases, especially when very small amounts of water are applied, such treatment plants are not economical, and thus the sewage is forwarded to local waste water treatment plants after a first coarse cleaning. Some sawmills have own water treatment plants. The little information which was found for Nordic countries and Eastern Europe shows comparable effluent load with organic compounds, ions and solids. No comparison could be made with Central and Southern Europe because only indirect data were available from which no specific data could be calculated.

The essential task of coarse water cleaning before sending to local waste water treatment plants is separation from mineral oil which mainly comes from diesel fuel used in the transportation processes.

4 The Bioenergy Flows - Pellets production

4.1 Introduction

For the case studies, M4 introduced in report PD 4.1.7 a simplified modelling approach for Bioenergy where the bark and black liquor combustion within Pulp and Paper industry is part of the processes, heat (or CHP) production within solid processing is as well part of the main processes. A more general description of the Bioenergy value chain is included in PD 4.1.7. Bioenergy technology development is described in report PD 4.2.3. To simplify modelling (ToSIA) only pellet production is recognizes as a own production process within M4 and therefore the only process for which data is collected.

4.2 Production process and detail sheet

Phases in a pellet production process in general is described in report PD 4.1.7 and shown in **figure 1**, including the energy input divided by type (electricity, heat, and diesel). For the regarded regions, countries were chosen with pellet production exceeding 100 kt/a. This means, that the pellet production level in that country equals to the level of at least one pellet model mill described here.

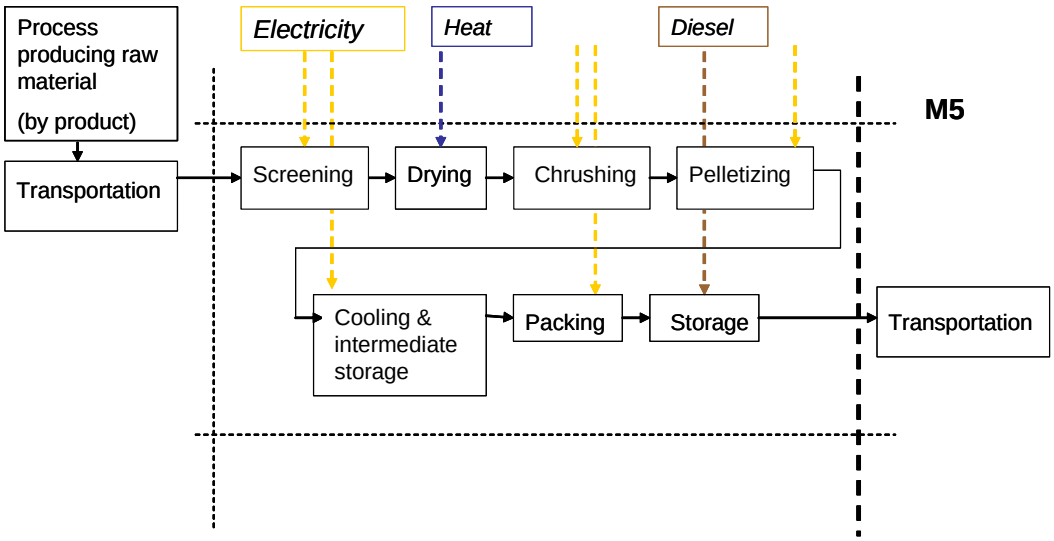

Figure 1. General process description of pellet production

The pellet production process utilize wood residue (mainly wet or dry sawdust) from saw mill industry as the process raw material. The production process includes several process steps. It starts with pre-treating the raw material before introducing it to the main production step, the pellet press. The extent of pre-treating needed depends of the quality of the raw material. The pre-treatment process normally consists of some kind of crushing and screening. Drying is not needed if the wood residue introduced to the process is dry (about 15 % water content). For the pellet production process in case

studies it is assumed that all of the raw material is dry which means that any assumptions considering drying are not included in the calculations.

Pre-treated raw material is carried by a feed screw to the pellet press, where pellets of the required size are produced. Steam may be used for improving the performance of the pelletizing. The compression process causes the raw material to heat up, releasing lignin which binds the material together. This gives the pellets their regular shape and shiny surface. After the manufacture step the pellets are cooled down before they are taken to storage. Wood pellets are typically supplied in the following ways: single small bags, small bags on pallets, bulk delivery for small consumers and bulk delivery for large consumers.

In the respective detail sheet, production capacity and utilization rate is included.

The production capacity of pellets has been growing very fast (about 30 % annually) during 2000 – 2005 and the capacity has continued to grow even faster after 2005 in Europe, in especially the Nordic countries (Sweden, Finland) and in some countries in Central Europe (especially Germany but also e.g. Italy). The Nordic countries had a production capacity of a little bit under 2500 kt (Sweden leading with 1400/1100 kt). The pellet production in Central Europe was about 1300 kt. Only Italy in Southern Europe had a production level over 100 kt/a. The pellet amount produced totally in 2005 was over 15 000 kt

The detail sheet of pellet production data is given in **table 6**.

Table 6. Detail sheet Pellet production

Production 2005

	Central and Eastern Europe	Nordic countries	Southern Europe
Production scale used for modelling, kt/a	80	80	80
Production (capacity) in chosen countries, kt/a	> 1300 (1560)	> 1500 (2250)	< 200 (200)
Average plant utilization rate, %	80	70	90
Assumption of raw material (weight % of produced pellets)			
- Saw dust from saw mills (w/d)	100 % (0/100)	100 % (0/100)	100 %
- Other wood resources	0 %	0 %	0%
Raw material use (input/output, weight)	1.06	1.06	1.06

Energy and steam production

	Central and Eastern Europe	Nordic countries	Southern Europe
Purchased electricity, MWh/t output	0.1	0.1	0.1
Purchased primary energy, MWh/t output	0.2	0.2	0.2
Composition of used fuels, %			
- Biomass	100	100	100

Information about sustainability indicators

	Central and Eastern Europe	Nordic countries	Southern Europe
Carbon content of product, %	45	45	45

Social information

	Central and eastern Europe	Nordic countries	Southern Europe
Specific number of employees, capita/t output	0.2	0.2	0.2

4.3 Economical and social aspects

The production costs for wood pellets are mainly influenced by the production scale, plant utilisation rate, by raw material costs and, in the case of using wet raw materials, by the drying costs. The production scale in EU-FWC studies is fixed (80 kt/a) for all countries. As the production capacity is presently growing very fast, the average utilisation rates are not very good (70 – 80%) in this affect (at least theoretically) on the production costs. Low plant availability also leads to greatly increased pellet production costs. A plant availability of 85–90% should therefore be achieved.

Wood pellet production is possible both in small-scale (production rates of some hundred tonnes per year) as well as in large-scale plants (some ten thousand tonnes per year). However, especially for small-scale units it is very important to take care of the specific framework conditions of the producer, because the risk of a non-economic pellet production is considerably higher than for large-scale systems. The economy of pellet production cannot be studied at the level described above within Eforwood studies. However, a simple calculation model that describes the production costs can be further developed. The cost of the raw material can be evaluated upon the market price for saw dust as energy. Furthermore, the average market price for pellets in different countries is quite well known.

The employment rate of a pellet plant depends on the plant utilization rate, which has influences on e.g. the number of shifts per week. The amount of personnel for each shift varies. Additional personnel for administration and marketing etc. is also needed. The average utilisation rate for pellet plants cannot be used to estimate employment – the figure would indicate a higher number than for a production plant with a reasonable utilisation rate. An average plant utilisation rate of 85-90% has therefore been used for estimating the employment effect of pellet production (0.2 capita/kt output) in all regarded European regions.

4.4 Environmental aspects

The environmental performance of pellet production in very much connected to energy consumption which again strongly depends on the quality of raw material used for pellet production (affects the need of energy for e.g. drying). Another parameter affecting energy consumption is the pelletizing technology used. The amount of energy needed is a sum of the energy need of sub processes; the energy input needed during the production chain is usually a blend of electricity, heat, steam and diesel (they cannot be summed together without defining e.g. primary energy input). Data describing energy consumption of the process may be grouped as electricity (net) about 100 kWh/t pellets, steam (net) about 25 in kWh/t pellets, heat (net) about 10 kWh/t pellets and diesel about 10 kWh/t pellets (or 1 l/t pellets). The use of electricity is the most important energy

indicator for pellet production from dry raw material dominating the production 2005. The total energy consumption, including electricity, steam, heat and diesel, expressed as primary energy, can roughly be estimated to 200 kWh/t for a dry pellet production process.

Emissions to air

The emission level of producing electricity, heat and steam depends on how it will be produced. E.g. the heat needed at a pellet plant is normally produced by wood residue or using produced pellets; the electricity is normally purchased.

Due to the reasons discussed above, total energy use (gross kWh per t pellets) and greenhouse gas emissions (kg CO_2 equivalents/t pellets) for the EU FWC can only be described very roughly. **Figure 2** shows the energy and material flows used for the pellet process in EU FWC 2005.

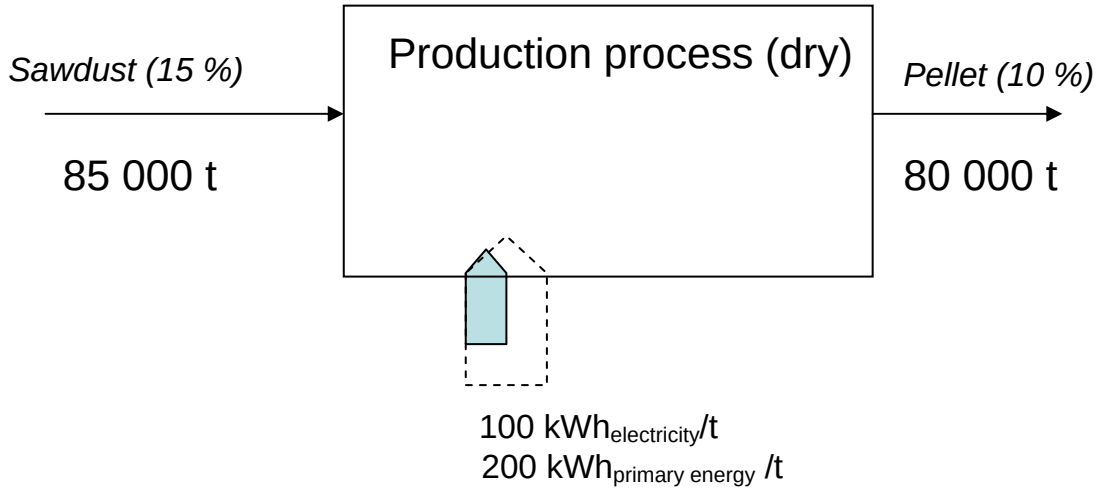

Figure 2. Energy and material flows for pellet production (80 000 t/a) in EU FWC 2005

5 Conclusion

This report was continuance to deliverable *PD4.1.7 Report describing the model mills in the case studies*. The same model mills were discussed in more detailed level in this deliverable. Special attention was given to differences between European regions, energy issues and environmental behaviour of the mills.

Pulp and paper production processes have some differences in different regions of Europe. In general it can be noted, that paper products contain less recycled fibre in Nordic Countries. This is mainly due to large export volumes to other parts of Europe, i.e. there is more production of paper than consumption of paper in the Nordic Countries. Paper mills are more often integrated to chemical pulping in Nordic Countries than in other regions because of the same reason. Non-integrated mills have higher fuel consumption, because the pulp mills are great producers of energy. Purchased fuel profiles in different regions of Europe cause differences to the amounts of emissions to air. In Nordic countries, mainly biofuels (e.g. bark) and natural gas are used, while in other parts of Europe also coal and oil may have important roles in steam production in the mills.

There are thousands of solid wood products and processes, and thus there is more variation in the solid wood industry than in the pulp and paper industry. This is why it has been difficult to generalize the processes, especially the secondary conversion processes, for this project in order to model them in a trustworthy but simple enough way. The importance of different solid wood product varies in different European regions, and because not 100% of solid wood production could be considered in this project, the most important products for each region were selected. This is why the products in each region vary, and it is difficult to make conclusions between the manufacturing of one product in different regions. The study focused on yields, output shares of different fractions and energy issues. Most of the energy is consumed in the drying processes.

Pellet production is a rather new process compared to other processes described in this report and that’s why pellet mills did not exist in all European countries in 2005. There are not huge differences in different regions of Europe, since technology and production equipments in pellet production is quite new. The process may be built in various ways, and the environmental aspects depend mainly on the energy production methods.

The concept of model mills will be discussed in another deliverable from Module 4 during the last year of Eforwood. WP4.3 will describe the upsides and downsides of model mill approach later on.