EFORWOOD

Sustainability Impact Assessment of the Forestry - Wood Chain

Project no. 518128

EFORWOOD

Tools for Sustainability Impact Assessment

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Report describing the Forest-based Case Study
"Scandinavian regional case"

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PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

PD 2.0.3: Report describing the Forest-based Case Study “Scandinavian regional case”

Coord: Erik Valinger (SLU)

Partners involved: Skogforsk, STFI, AIDIMA, Jakoo Pöyry

Researchers involved: E. Valinger (SLU)
S. Berg (Skogforsk)
A. von Schenk (STFI)
G. Verhaege (AIDIMA)
M. Johansson (STFI)
H. Lehtinen (Jakoo Pöyry)

Abstract:

This report provides an overview of the agreed terms of reference of the task force “Scandinavian regional case” and the management structure for this case study. It summarises discussions on the structure of the case study “Scandinavian” to date, and activities undertaken and further steps by all partners involved to define the boundaries of the regional case study “Scandinavian” and organise and manage communications, data collection and quality assessment of the data provided for the agreed set of sustainability indicators to feed into the ToSIA database. Furthermore, it exemplifies the work performed within the case study up to date. This report presents preliminary results and therefore the final outcome of the case study will be completed and somewhat changed in the future development stage of the project.

Key words*: forest-wood chain, regional case study, sustainability impact assessment,*

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1 Agreed Terms of Reference/ Role of the task force

The Task Force agreed on the following tasks to define the regional case study “Scandinavian”:

- to define the region of interest in its physical, geographical or political boundaries (1)
- to define the relevant single chains (from M2 to M5) covering 60-80% of wood material present in the region defined (2)
- to agree upon the interfaces between all modules (i.e. type and structure of data, additional information required such as quality requirement for specific chains) (3)
- to define all processes within each chain, and links between the different chains (4)
- to provide an verbal overview of the case study to describe the links and interfaces between modules and chains defined (5)
- to agree upon measures to verify consistency of data across modules and single chains (6)
- to evaluate outputs of ToSIA for different scenarios/different weighting of indicators according to MCA on the case study level and provide interpretation of the results (7)
- to establish permanent links of communication and information flow between all partners involved to ensure common understanding of tasks and agreement on approaches (8)
- to ensure that all deadlines concerning the definition of the case study, data collection and provision to M1 are met (9)

2 Management of the case study

The case study “Scandinavian” is coordinated by Module 2. Partner 21 (SLU) will act as the coordinator and will ensure that the agreed terms of references and all deadlines are met. Modules 3, 4 and 5 will be presented in the task force group by the nominated participants.

Nominated participants / contact persons

	M2	M3	M4	M5	M1
Scandinavian regional case	**E. Valinger** (SLU)	S. Berg (Skogforsk) Lars Wilhelmsson (Skogforsk)	A. von Schenk (STFI) [fibres]	G. Verhaege (AIDIMA) [wood] Martin Johansson (STFI) [fibres] H. Lehtinen (Jakoo Pöyry) [bioenergy]	
Baden-Wuerttemberg regional case	H. Spiecker Ph. Duncker (ALU-FR) J. Zell (FVA)	**F. Bruechert** (FVA)	K. Livesey (BRE) [wood] A. von Schenk (STFI) [fibres] M. Wihersaari (VTT) [bioenergy]	G. Verhaege (AIDIMA) [wood] Martin Johansson (STFI) [fibres] H. Lehtinen (Jakoo Pöyry) [bioenergy]	A. Trasobares
Iberian regional case	M. Tomé M. Palahi G. Chantre (AFOCEL)	S.-O. Lundqvist (STFI)	A. von Schenk (STFI) [fibres]	**I. Bryne** (AIDIMA) G. Verhaege (AIDIMA) [wood] Martin Johansson (STFI) [fibres] H. Lehtinen (Jakoo Pöyry) [bioenergy]	

Communications:

- day-to-day communication will be ensured by email, a contact list will be provided by the CS coordinator
- regular telephone conferences of the task force group will be held to ensure agreement on decisions taken and continuous up-date on work progress
- meetings of the task force group will be held during the up-coming EFORWOOD weeks to allow presentations of results and discussion on the approach agreed to date
- on the EFORWOOD portal, a section will be reserved for the case study to upload information and data and allow access to information required for all partners to follow the progress of the work

3 Status report on the preliminary definition of the regional case study “Scandinavian”

1. The Scandinavian case is based on the whole County of Vaesterbotten, and the agreed single chains should cover 60-80% of wood harvested in the region. Besides the three main species we agreed upon M2 presenting all species in the case study area. However, only pine, spruce, and birch are included in the case study. It was also decided that M3 should investigate if there are differences between the different parts of Vaesterbotten regarding the logistics.
2. The reference year for the Scandinavian case study will not be 2005 as earlier agreed. The mean values for the years 2001-2005 will be used instead.
3. M2 has collected the basic data for the Scandinavian case study. All figures in section 4 below refer to the forest area in Vaesterbotten, i.e. the area that is suitable for forest production and where the annual production is higher than 1 m^3/ha, year.) As already stated, all figures represent the situation within the period 2001-2005. The year 2005 has not been chosen because it was an exceptional year regarding cutting also in northern Sweden, not just following the storm Gudrun in southern Sweden. That year 33% more wood were cut.
4. The basic forest resources data for Vaesterbotten have been transferred to M3, which has carried out calculations of costs, time expenditure, use of fuel and lubricants and harvested timber. M3 has also allocated cut volume to industry products and described to wood flow from the forest to industries within and outside Vaesterbotten.
5. Their data have been submitted to M4 which has described the utilization of the wood flow and the consumption in more detail for the fibre chain and the solid wood chain. Contribution from M5 will complete the future report on Scandinavian case study (PD 2.0.5).

4 Forest resources (Erik Valinger)

4.1 Forest area

The total forested area of Vaesterbotten comprise 1 861 000 ha (inland), and 1 318 000 ha (coastal) = a total of 3 179 000 ha (in these areas forest area without trees are included).

4.2 Species

The proportion of Scots pine, Norway spruce and Birch dominated forests is approximately 70% of the total area.

Table 4.1. *Species area distribution in Vaesterbotten*

Forest type	Proportion inland, %	Inland, ha	Proportion coastal, %	Coastal, ha	Total proportion, %	Total, ha
Pine1	39.3	730 799	49.3	649 523	43.4	1 380 323
Spruce1	27.6	514 170	13.4	176 761	21.7	690 930
Birch1	4.8	89 533	3.5	46 182	4.3	135 715
Other2	22.1	411 046	27.3	360 722	24.3	771 768
Lodgepole pine1	3.9	72 798	2.3	30 017	3.2	102 815
Bare ground	2.3	42 738	4.2	55 203	3.1	97 941
Total, ha		1 861 083		1 318 408		3 179 491

[1]Pine, spruce, birch and contorta dominated forests (>70% of basal area)
[2]Mixed conifer forests (No conifer species >70% of basal area) + Mixed forests (between 40% and 60% broadleaved trees)

4.3 Cutting classes

More than 50% of the forest areas can be managed with thinning, i.e. cutting classes C, E and D1. About 20% of the area can be clear-cut, i.e. D2. The definitions of the different cutting classes can be found below the table.

Table 4.2. *Cutting class distribution in Vaesterbotten*

Cutting class	Proportion of area, %	Area, ha	Growing stock, m3/ha
A	4.2	133130	15
B1	7.9	251617	10
B2 + B3	20.2	642490	19
C + E	36.2	1149856	107
D1 + D2	31.5	1002398	154
All	100	3179491	92

Clarifications on definitions:
A (Regeneration, bare ground)
B1 (Regeneration, plant forest. Mean height < 1.3 m)
B2 (Young forest, mean height between 1.3 m and 3 m)
B3 (Young forest, mean height > 3 m. Dominating and co-dominating trees smaller than 10 cm at 1.3 m)
C (Medium forest. Most dominating and co-dominating of trees larger than 10 cm at 1.3 m)
D1 (Adult forest. Age is lower than recommended clear-cut age)
D2 (Adult forest. Age above recommended clear-cut age)
E (Forest suitable for single tree selection)

For sites classified as pine forests the largest proportion of the area is within the cutting class thinning (C + E). 64% of the forest area is classified as being most suitable for pine.

Table 4.3. *Area distribution in cutting classes for Scots pine in Vaesterbotten*

Cutting class, pine	Proportion of total forest area, %	Area, ha
A	3.1	99366
B1	5.4	172350
B2 + B3	15.9	505262
C + E	26.4	838662
D1 + D2	13.4	427569
All pine	64.3	2043209

For sites classified as spruce forests the largest proportion of the area is within the cutting class adult forest (D1 + D2). 35.7% of the forest area is classified as being most suitable for spruce.

Table 4.4. *Area distribution in cutting classes for Norway spruce in Vaesterbotten*

Cutting class, spruce	Proportion of total forest area, %	Area, ha
A	1.1	33764
B1	2.5	79268
B2 + B3	4.3	137228
C + E	9.8	311195
D1 + D2	18.1	574828
All spruce	35.7	1136283

4.4 Year classes

When the area is divided in the following year classes it can be seen that 60% of the forest area in Vaesterbotten holds trees older than 41 years.

Table 4.5. *Year classes distribution in Vaesterbotten*

Year class	Proportion of area, %	Area, ha	Growing stock, m3/ha
0-	4.0	127 160	11
3-	8.4	267 036	10
11-	10.6	336 974	14
21-	10.1	321 079	33
31-	6.8	216 172	64
41-	14.6	464 134	102
61-	10.3	327 437	141
81-	9.7	308 363	140
101-	8.5	270 215	154
121-	8.6	273 394	168
141-	8.4	267 036	164

4.5 Productivity

Almost 80% of the forested area has a productivity below 4 m^3/ha, year.

Table 4.6.*Productivity classes distribution in Vaesterbotten*

Productivity, m3/ha, yr	Proportion, %	Area, ha	Groving stock, m3/ha
0-	6.2	196 787	74
2-	31.3	996 412	83
3-	39.9	1 270 021	98
4-	18.1	574 052	99
5-	4.1	129 164	102
6-	0.3	8 886	154
7-	0.1	4 169	184

4.6 Diameter distributions

The species Scots pine, Norway spruce and Birch stands for more than 95% of the growing stock. About 1% of the volume can be found in Scots pine and Norway spruce trees larger than 45 cm at breast height.

Table 4.7. *Diameter distribution for species present in Vaesterbotten*

Species	Diameter at breast height, cm								
	0-9	10-14	15-19	20-24	25-29	30-34	35-44	45-	Total	Proportion
	milj. m3									%
Pine	7.7	17.8	30.8	30.3	21.3	14.1	8.4	0.9	131.4	43.6
Spruce	9.4	17.4	24.0	21.6	15.9	11.3	7.6	2.9	110.1	36.5
Betula	12.5	13.6	10.5	5.5	2.4	0.6	0.3		45.4	15.1
Contorta	1.1	0.7	0.1	0.0					2.0	0.7
Populus	0.1	0.3	0.4	0.3	0.2	0.2	0.3	0.1	1.9	0.6
Alnus	0.3	0.2	0.1	0.0					0.7	0.2
Salix	0.2	0.3	0.3	0.3	0.2	0.1	0.2	0.0	1.6	0.5
Sorbus	0.1	0.0	0.0	0.0					0.2	0.1

Dry + wind-thrown	1.2	1.7	1.4	1.2	0.7	0.5	0.8	0.5	8.0	2.7
All	32.7	52.0	67.7	59.3	40.8	26.9	17.6	4.4	301.5	100

4.7 Increment

The total increment of Scots pine is 4 610 000 m^{3}, of Norway spruce 3 310 000 m, and of birch 2 000 000 m^{3}. The mean annual increment is 3.0 m^{3}/ha.

4.8 Dead wood

The mean amount of deadwood for Vaesterbotten is 7 m^{3}/ha. It can be seen that a trend is that the amount of dead wood increases with cutting class and year class.

Table 4.8. *Dead wood distribution within cutting classes and diameter classes in Vaesterbotten*

	Year class						
	-20	21-40	41-60	61-80	81-100	101-	All
Cutting class	Volume, m3/ha						
A	3		0	0		4	3
B1	7	0		18		9	7
B2+B3	4	3	4	1		6	4
C+E	1	4	4	5	5	11	4
D1	0			10	6	10	8
D2		0	2	15	12	19	18
Alla	5	4	4	5	6	16	7

When divided into the different species and development phases it can be seen that the described trend is even more pronounced. Most dead wood can be found in sites suitable for single tree cutting of spruce, i.e. 29 m^{3}/ha.

Table 4.9. *Dead wood distribution within development phases for pine, spruce, birch and mixed forests in Vaesterbotten*

Species	Development phase	Area, ha	Standing, m3/ha	Lying, m3/ha	Total, m3/ha
Pine	Young	440569	1	4	5
	Medium 1	540364	1	3	4
	Medium 2	79271	2	5	7
	Adult	54007	5	6	11
	Natural regeneration	240018	3	3	6
Spruce	Young	132743	0	1	1
	Medium 1	85560	1	3	4
	Medium 2	43641	2	5	7
	Adult	289271	8	13	21
	Single tree cutting	33207	19	10	29
Mixed	Young	272027	0	3	3
	Medium 1	109145	3	2	5
	Medium 2	71765	3	3	7
	Adult	118085	5	6	11
Birch	Young	48768	0	5	5
	Medium	17060	2	1	3
	Adult	24128	7	12	19

4.9 Cuttings

The annual cutting area on forest land is 112 000 ha with a mean cut of 70 m^3/ha.

Table 4.10. *Area and volume per ha of cutting in different silvicultural stages in Vaesterbotten*

Cutting	Inland, ha	Volume/ha, m3/ha	Coastal, ha	Volume/ha, m3/ha	Total, ha	Volume/ha, m3/ha
Clear felling	11 000	180	18 000	184	29 000	183
Thinning	8 000	43	26 000	70	34 000	63
Cleaning	16 000	4	21 000	6	38 000	5
Others	5 000	44	7 000	33	12 000	39
Total, ha	41 000	61	71 000	75	112 000	70

The mean annual cut for Vaesterbotten during the years 2001-2005 is 7.8 million m^3/year. Approximately two thirds of that volume is cut in the coastal region.

Table 4.11. *Total volume of cutting in different silvicultural stages in Vaesterbotten*

Cutting	Inland, Volume/yr, m3/yr	Coastal, Volume/yr, m3/yr	Total volume/yr, m3/ yr
Clear felling	1 915 000	3 310 000	5 224 000
Thinning	365 000	1 808 000	2 173 000
Cleaning	66 000	126 000	192 000
Others	123 000	106 000	230 000
Total, ha	2 470 000	5 350 000	7 819 000

During the 2001-2005 period 50.1% of all cuttings was Norway spruce (3 916 952 m3/yr) 41.4% Scots pine (3 231 110 m3/yr), and 8.5% Birch (661 752 m3/yr).

Table 4.12. *Total volume of cutting in different silvicultural stages for pine, spruce, and birch in Vaesterbotten*

Cutting		Inland, Volume/yr, m3/yr	Coastal, Volume/yr, m3/yr	Total volume/yr, m3/ yr
Clear felling	Pine	527531	1634972	2162503
	Spruce	1281446	1570850	2852297
	Birch	105772	101774	207545
Thinning	Pine	228344	677324	905668
	Spruce	120208	821049	941256
	Birch	16586	301638	318224
Cleaning	Pine	16644	35075	51719
	Spruce	17194	12288	29482
	Birch	32547	78319	110865
Others	Pine	36246	74974	111220
	Spruce	71094	22823	93917
	Birch	16103	9017	25120
Total, m3/yr		2469714	5340102	7809817

4.10 Natural regeneration of pine

The potential areas for natural regeneration of pine areas (earlier defined silvicultural regimes in PD2.1.1 “Desciption of forest production processes: report including analysis and description of current production processes for various relevant sites and forest types”) was established by using the following criteria’s:

1. Ground vegetation myrtillus or worse.
2. Cutting class D.
3. More than 50% of basal area should be pine.
4. Sites should be situated ≤ 300 m a.s.l.

About 7.5% of the forest land met the criteria’s and could be regarded as potentially suitable for natural regeneration of pine.

Table 4.13.*Area suitable for natural regeneration of pine in Vaesterbotten*

Area	Ground vegetation	Cutting class		
		D1	D2	D1 + D2
Inland	< Myrtillus	24778	28445	53223
	Other	.	1903	1903
	Total	24778	30348	55126
Coast	< Myrtillus	79235	101170	180406
	Other	1242	3245	4487
	Total	80477	104415	184892
Total	< Myrtillus	104013	129615	233628
	Other	1242	5148	6390
	Total	105255	134763	240018

4.11 Single tree cutting of spruce

The potential areas for single tree selection of spruce areas (earlier defined silvicultural regimes in PD2.1.1 "Desciption of forest production processes: report including analysis and description of current production processes for various relevant sites and forest types") was established by using the following criteria's:
Ground vegetation myrtillus or better.

1. Thinning- and Clear-cut forests (Cutting classes C and D).
2. More than 70% of basal area should be spruce.
3. Stand structure. From the diameter of the largest tree in diameter, four diameter classes are created by the construction of the quota dmax/4. The shares of the number of trees (n) within each diameter class are the basics in defining the stand structure classes. Suitable stands are stands with quotas n1/n2, n2/n3, n3/n4 > 1.0, all other are not acceptable.
4. Growing stock > 150 m3/ha.

About 1% - 6% of the forest land met the criteria's and could be regarded as potentially suitable for single tree cuttings of spruce. The difference between what was regarded as suitable and not suitable was that criteria 4 was not fulfilled for the column Not suitable.

Table 4.14.*Area suitable for single tree cutting of spruce in Vaesterbotten*

Area	Single tree selection, ha		
	Not suitable	Suitable	Total
Inland	97331	22182	119513
Coast	68650	11025	79675
Total	165981	33207	199189

4.12 Starting values for reference forests

Examples of the starting values for the reference forest of Västerbotten can be seen in the following figures (Figure 4.1- 4.6). The reference ages for the time of the planned silviculture measure varies between the stand types (Figure 4.1).

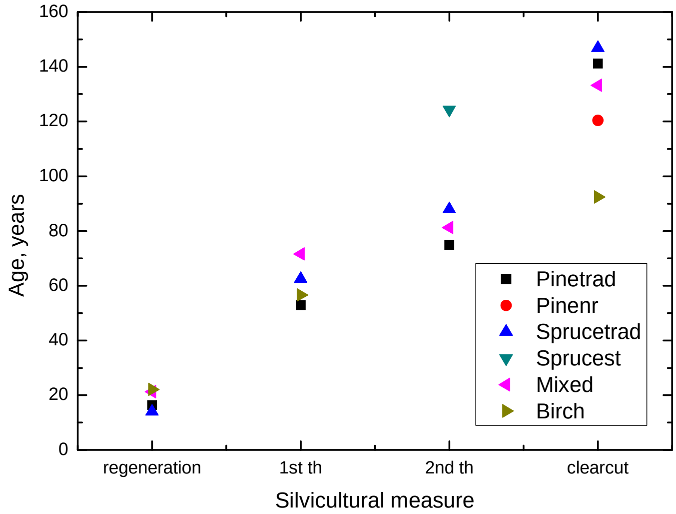

Figure 4.1 *Ages at different phases of development for the different stand types.*

As can be seen (Figure 4.2) there are up to 100 large trees at sites at the regeneration phase, which probably has to do with the demands of leaving trees at clear-cut for environmental purposes.

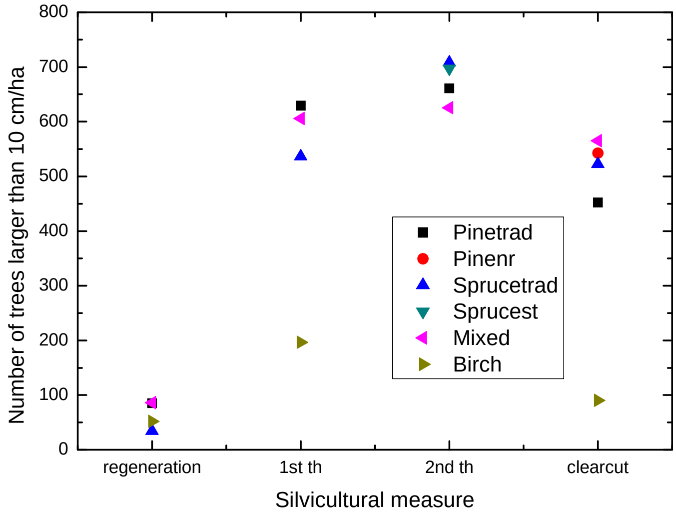

Figure 4.2 *Number of trees at different phases of development.*

There are almost 4 m difference in mean height between Scots pine and Norway spruce trees and sites which includes Birch at First thinning (Figure 4.3).

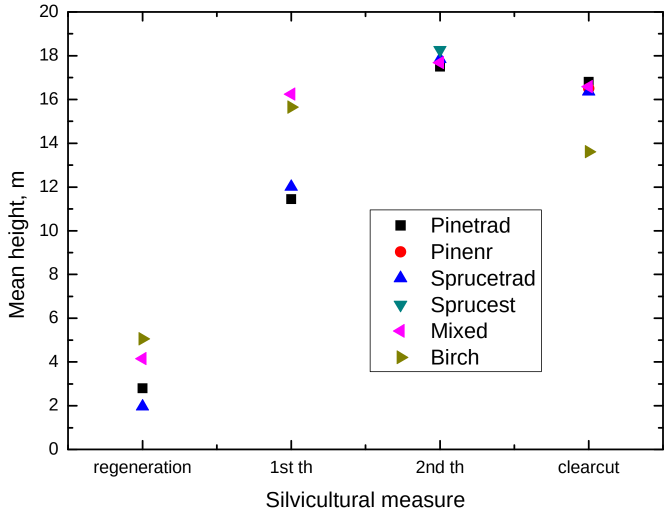

***Figure 4.3** Mean heights at different phases of development .*

The high initial growth of sites with Birch can also be traced when looking at the development of basal area over time (Figure 4.4).

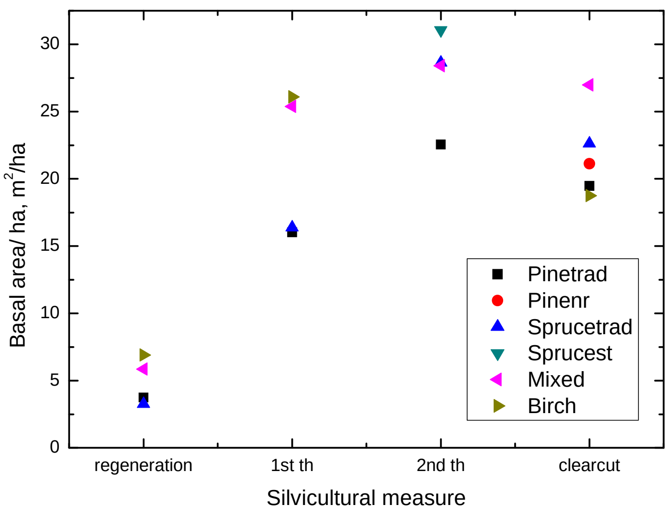

***Figure 4.4** Mean basal area at different phases of development.*

The highest volumes can be found at sites dominated by spruce at second thinning (Figure 4.5).

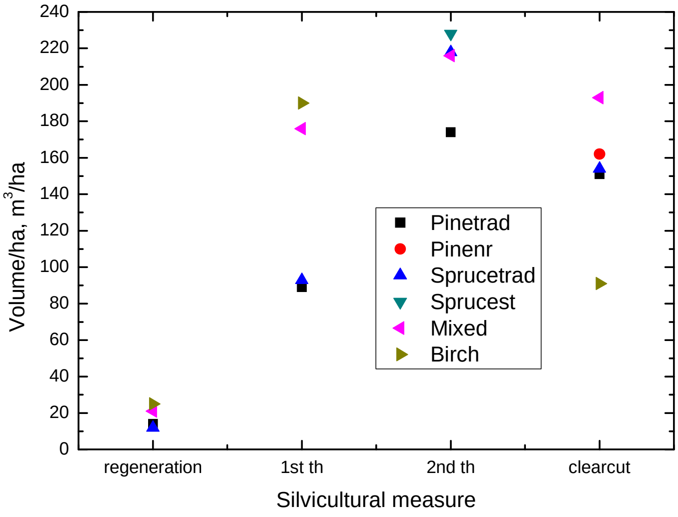

Figure 4.5 *Mean volumes at different phases of development.*

The figures above were some examples of data delivered to M3 for the Scandinavian case.

5 Forest to Industry (Staffan Berg, Lars Wilhelmsson)

5.1 Work description

- Harmonized description of **machine parameters** within this case study and other cases.
- Identification of forest operations for eight chains, pine, spruce, mixed, birch, with variations even-aged and uneven aged.
- These chains contain operations
- They are described with stand data according to a designed parameter **data sheet**.
- With this data **costs, time expenditure**, use of **fuel** and **lubricants** and **harvested timber** volumes are to be calculated.
- Costs and productions are still not evaluated because it has not been possible to identify the **representative cut in thinnings**.
- Harvested volumes can be modeled for allocation to **industry products.**
- To calculate results according to above in each operation box

Table 5.1. *Silvicultural measures in different development phases for pine, spruce, and birch forests in Vaesterbotten*

stage	pine			spruce		birch	
silvicultural treatment	even-aged	even-aged	even-aged	even-aged	uneven-aged	even-aged	even-aged
regeneration	planting pest control	seeding	nat. reg.	planting pest control	nat. reg.	planting clearing 1	nat. reg. clearing 1
young stand	clearing 1	clearing 1	clearing 1	clearing 1		clearing 2	clearing 2
medium	clearing 2 fertilization?	clearing 2 fertilization?	clearing 2 fertilization?	fertilization? thinning 1			
adult	thinning 1 fertilization? drainage? final harvest	thinning 1 fertilization? drainage? final harvest	thinning 1 thinning 2 fertilization? drainage? final harvest	thinning 2 drainage? final harvest	thinning(s)	thinning 1 final harvest	thinning 1 final harvest

5.2 Transport

In this raw material driven case transports are made with road vehicles (Inside and out of case study area) and railways, mostly out of area. Total volumes, means and distances shipped to individual industries for primary industrial use has been identified for 2004 (was easily available). Updating is going on for 2005 level of volumes.
The above assessments are is good for traditional l forest industry assortments,
Only a part of the biofuel amounts are identified through statistics, other methods are to be used here and we rest on a material from Svebio, the Swedish biofuel organization.

- In this raw material driven case transports are made with road vehicles (Inside and out of case study area) and railways, mostly out of area.
- Total volumes, means and distances shipped to individual industries for primary industrial use has been identified for 2004 (was easily available).
- Updating is going on for 2005 level of volumes.
- The above assessments are is good for traditional l forest industry assortments.
- Only a part of the biofuel amounts are identified through statistics, other methods are to be used here and we rest on a material from Svebio, the Swedish biofuel organization.
- Identification of forest industries outside Västerbotten area.

Input data from M2, Lars Wilhelmsson, SKA 99, and Rikstaxen (27.9 2006) has been used for calculation of outcomes of cuttings.

Table 5.2. *Outcomes of cuttings in Vaesterbotten*

Variable	Final	Thinning
Arithmetic mean stem m3fub	0,36	0,17
D b.H. cm	21,2	15,9
Vol/ha m3fub	180	55
St/ha	500	320

Together with information from Companies and judged by experts this information has been broken down into the cost assessment sheets to

Table 5.3. *Adjusted outcomes of cuttings in Vaesterbotten*

Variable	Final	Thinning
Arithmetic mean stem m3fub	0,36	0,17
D b.H. cm		
Vol/ha m3fub	180	53
St/ha	500	320

Thinning with a share of saw timber of 30%, giving 0.17 m^3 per tree, 16.7 m^3/h, and 53 m^3/ha. In final felling the share of saw timber of 70%, which means 0.36 m^3 per tree, 37m^3/h, and 180 m^3/ha

5.3 Wood characteristics for reference forests

Within this chapter, examples of the wood characteristics after bucking simulation of properties that can be used in the following work within the Scandinavian case study are presented. The characteristics have been calculated for Sots pine dominated sites (Figures 4.6-4.12). The models used were from Skogforsk, STFI and SLU.

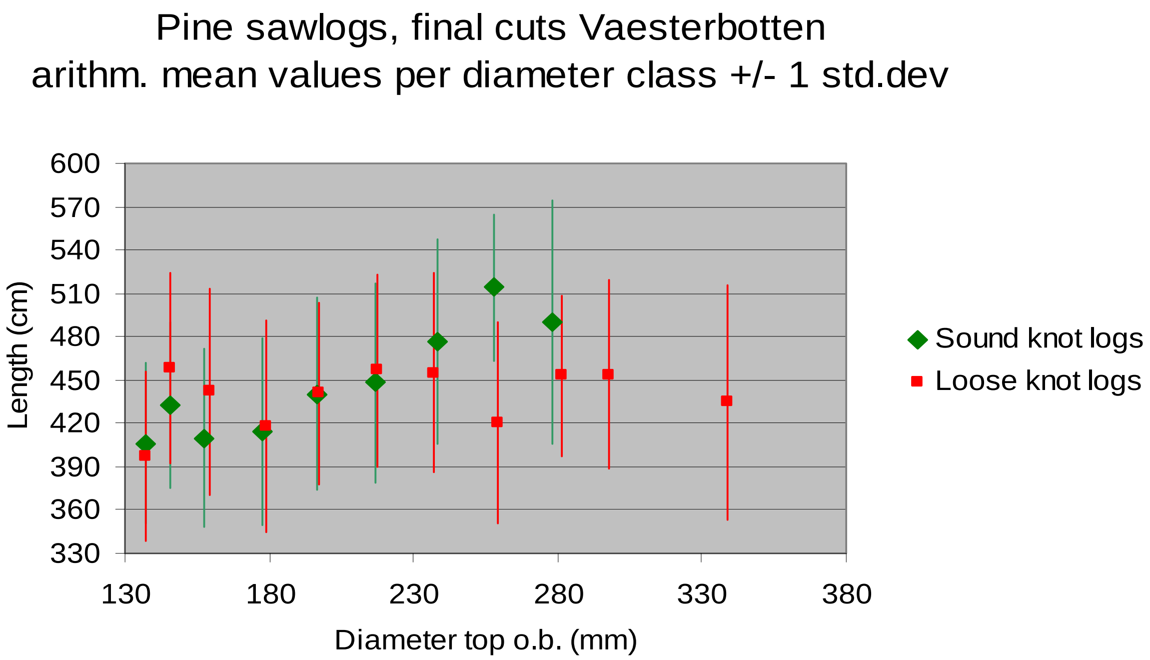

Figure 5.1 *Length of pine sawlogs at final cutting.*

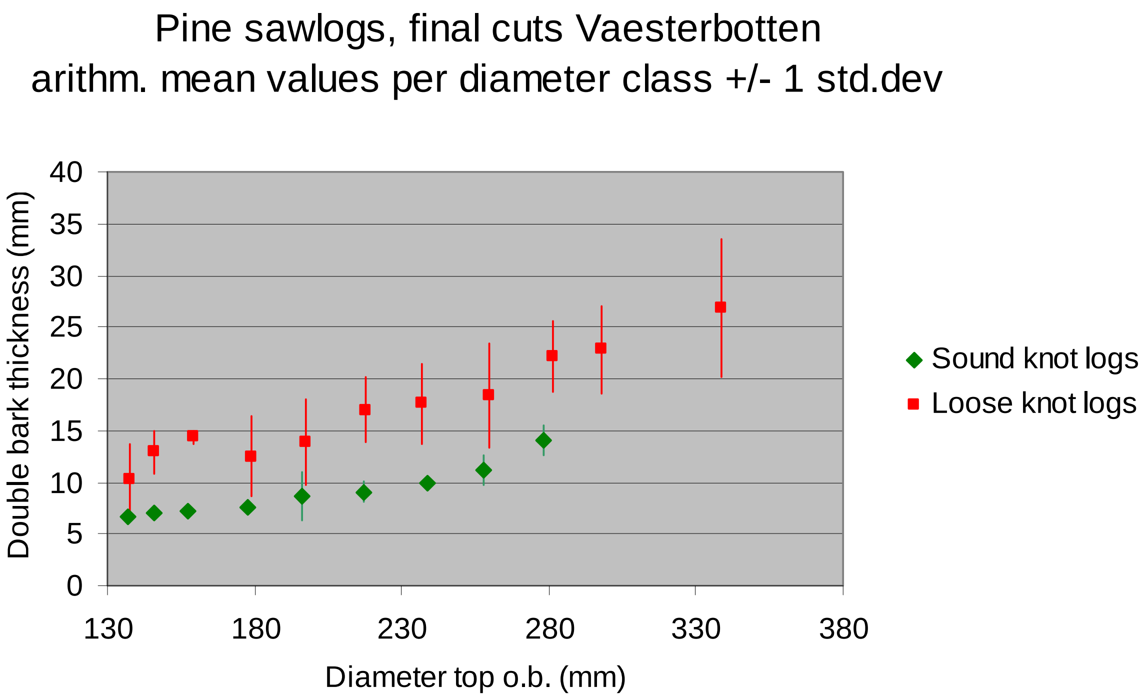

Figure 5.2 *Double bark thickness of pine sawlogs at final cutting.*

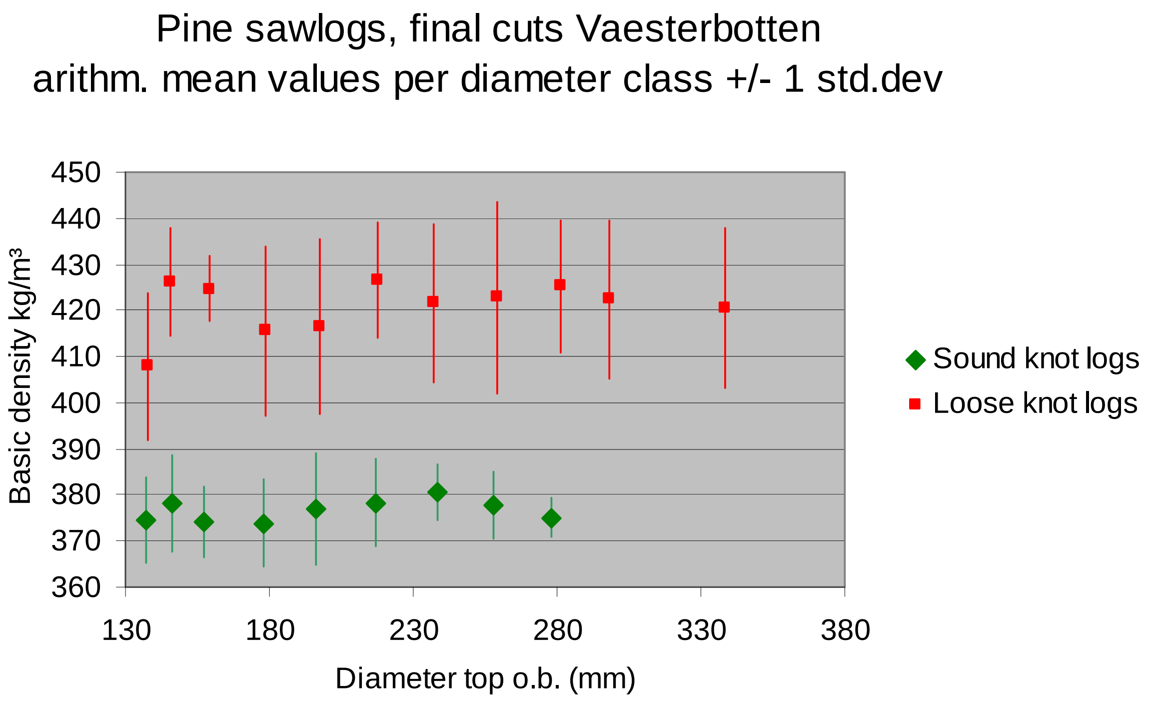

Figure 5.3 *Basic density of pine sawlogs at final cutting.*

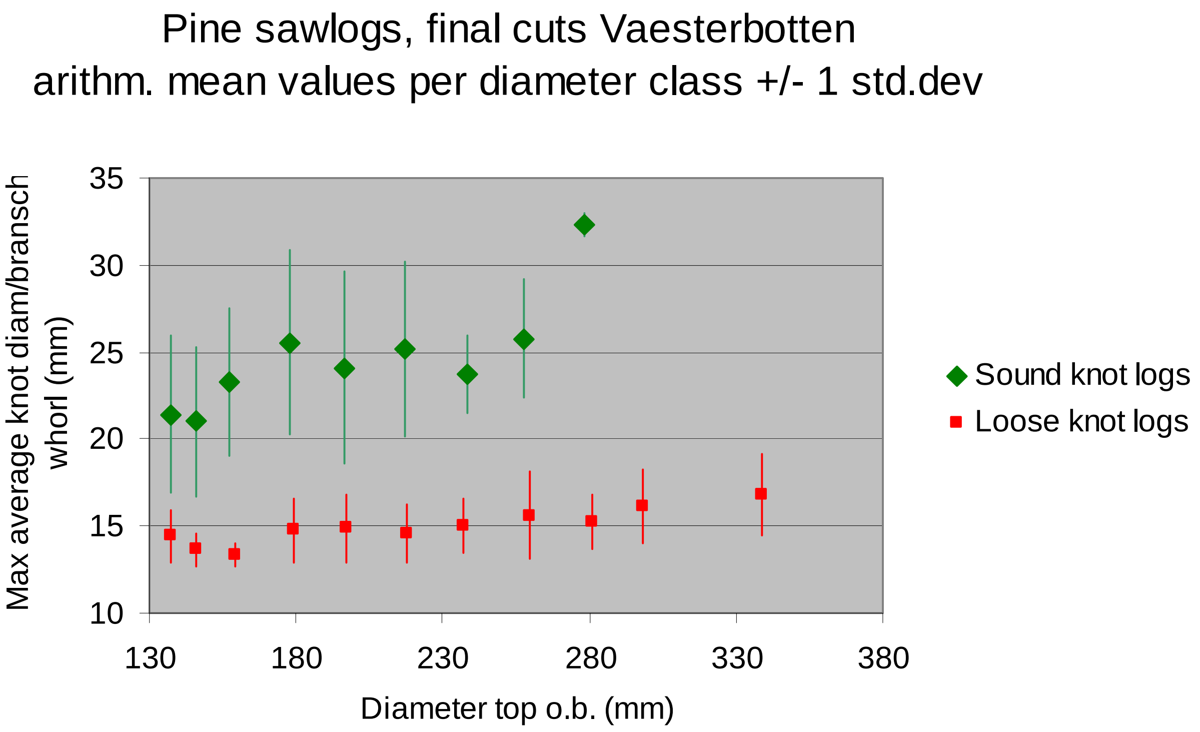

Figure 5.4 *Maximum average diameter/branch whorl of pine sawlogs at final cutting.*

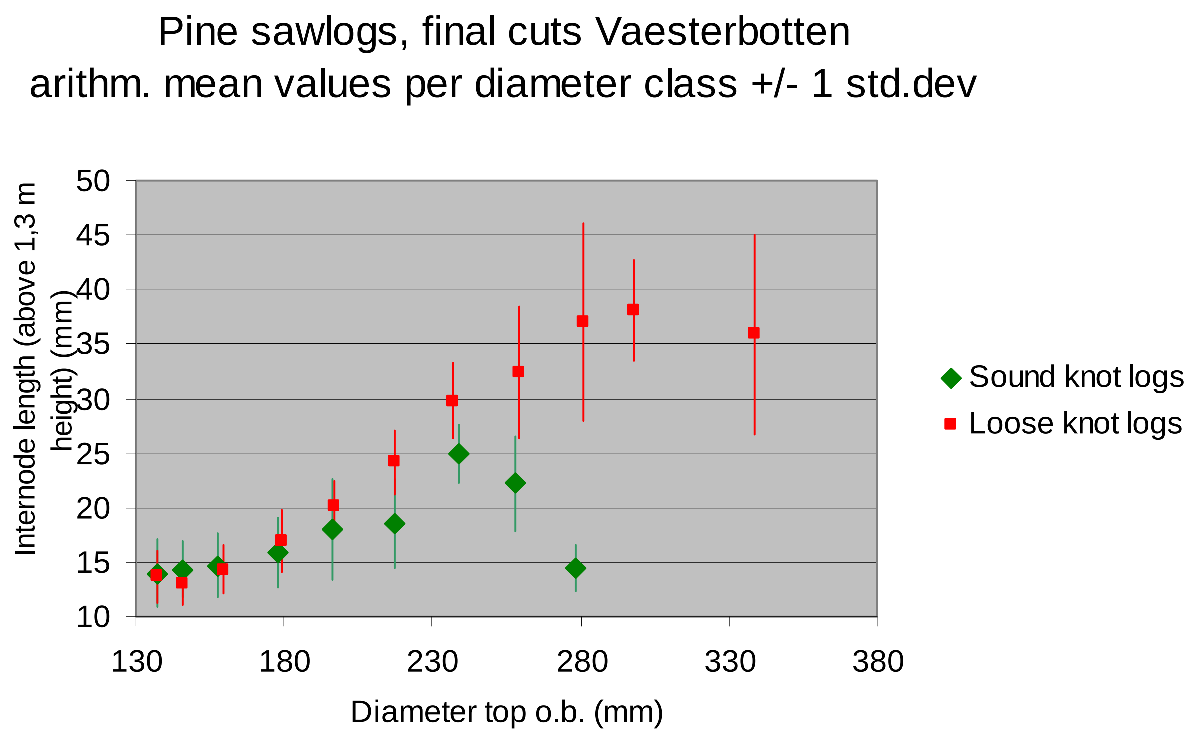

Figure 5.5 *Internode length above 1.3 m height of pine sawlogs at final cutting.*

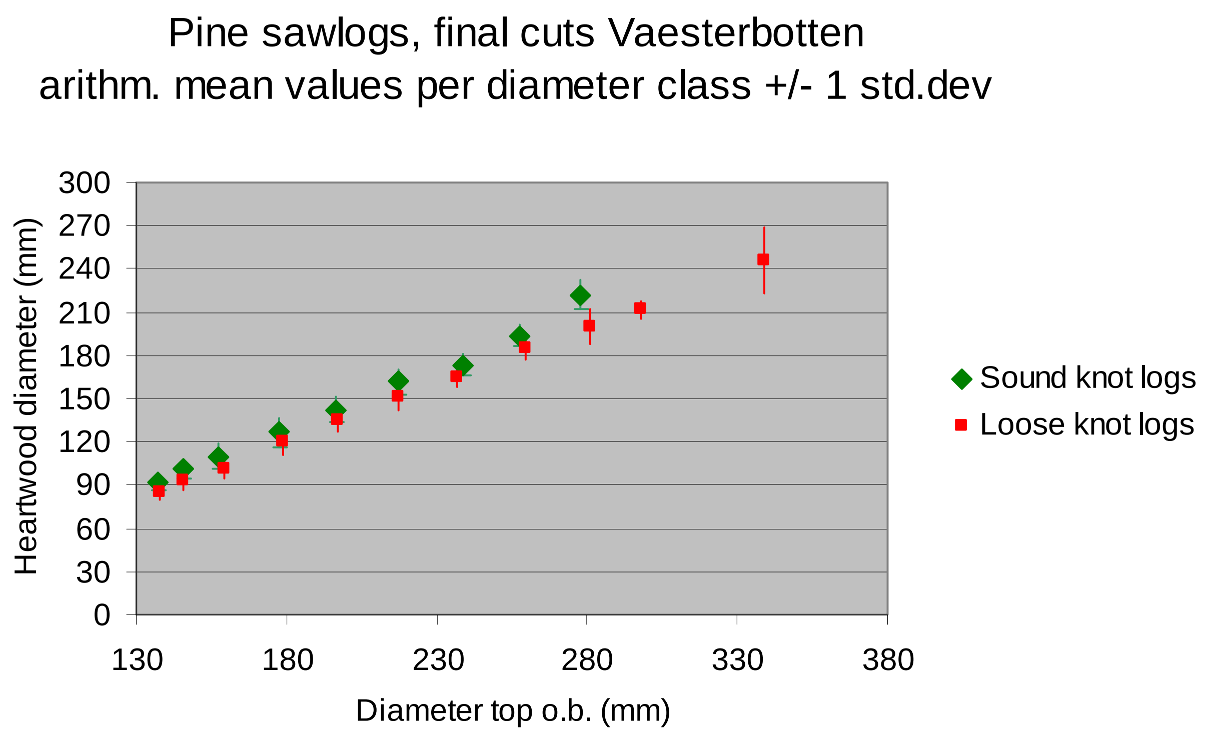

Figure 5.6 *Heartwood diameter of pine sawlogs at final cutting.*

Table 5.4 *Pine pulpwood from final cuts, Case study Vaesterbotten*
Arithmetic means. Total volume of pulpwood was predicted to be 22% of harvested volume

	Vol m3s ob	Bark Proc ob	Top Dia_ ob	Bolt Lengt h	Dens	Heart-Diam	Heartw cont	Mean_Dbl_ Barkthickn	Late-wood
average	0,04876	12%	96	425	383	64	27%	8	24%
Stdev	0,02707	0,0	37	60	23	26	7,8%	3	3

	AnnGrRing	Fibre Length	Fib. Wall	KD Max	Green DensUb	Green Bark Dens	Defect Log	Mass kg	Inter-node
average	0,7	2,42	2,23	17,8	873	813	7,5%	47	12
Stdev	0,2	0,17	0,08	4,5	23	31		24	4

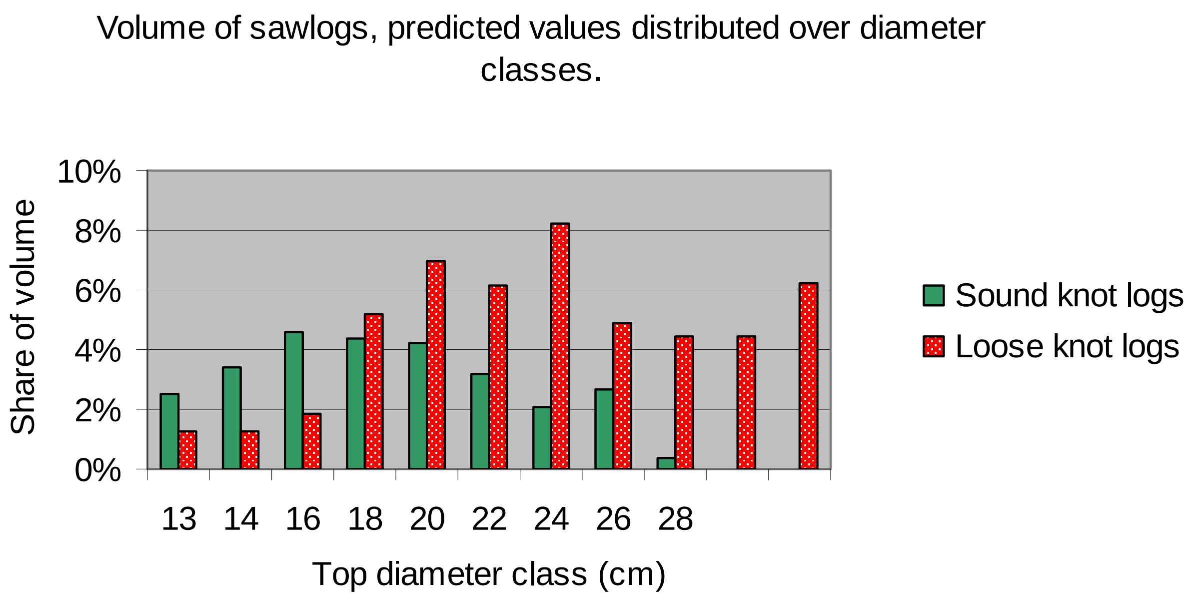

Figure 5.7 *Share of pine sawlogs over diameter classes at final cutting.*

6 Processing and manufacturing – fibre chain (Anna von Schenck)

6.1 Background –The Fibre value chain

For the fibre value chain 5 different processes have been defined representing the different kind of pulp and paper mills in Europe.

The processes defined are:

- Bleached Market Pulp Mill
- Integrated Fine Paper Mill
- Kraftliner Mill
- Magazine Paper Mill
- Newsprint Mill

STFI-Packforsk is responsible for the description of the model mills for:

- Bleached Market Pulp Mill
- Integrated Fine Paper Mill
- Kraftliner Mill
- Magazine Paper Mill
- Ev. Newsprint Mill

The Bleached Market Pulp Mill, The Integrated Fine Paper Mill, The Kraftliner Mill and The Magazine Paper Mill have been developed within the framework of the Swedish national research project called FRAM in collaboration with Ångpanneföreningen AB.

The system analysis in the "Future Resource-Adapted Pulp Mill" program (FRAM, 2003-2005) is a continuation of the work carried out in the "Ecocyclic pulp mill" program (KAM, 1996-2002). In KAM the focus of the system analysis was on a theoretical *"reference mill"*, a hypothetical pulp mill which represents the existing best available, commercially proven, Nordic technology at the time of writing. It was assumed to be built as a greenfield mill. In FRAM has the reference mill been updated. In addition to the reference mills, *"type mills"* have been included representing typical mills of today in Nordic countries. Some adjustments have been made to make them represent the mills studied for the different case studies taken into account the material use in different regions in Europe.

The Newsprint Mill has been defined in collaboration with KCPK

6.2 The Scandinavian case study

For the Scandinavian case study, 2 pulp and paper mills will be defined:

- Kraftliner Mill in the Västerbotten region
- Integrated Fine Paper Mill close to the Västerbotten region

It is the production rate and raw material use for the Type Mills that will be used for the base year 2005.

6.3 Kraftliner Mill

6.3.1 Reference mill, kraft liner mill

The liner mill has two paper machines with the same design. One machine normally produces unbleached liner and the other white top liner. Unbleached kraft pulp is produced in the integrated kraft mill, whereas the bleached pulp is purchased. Apart from the kraft pulp also a considerable amount of recycled fibres is used, especially in the unbleached liner.

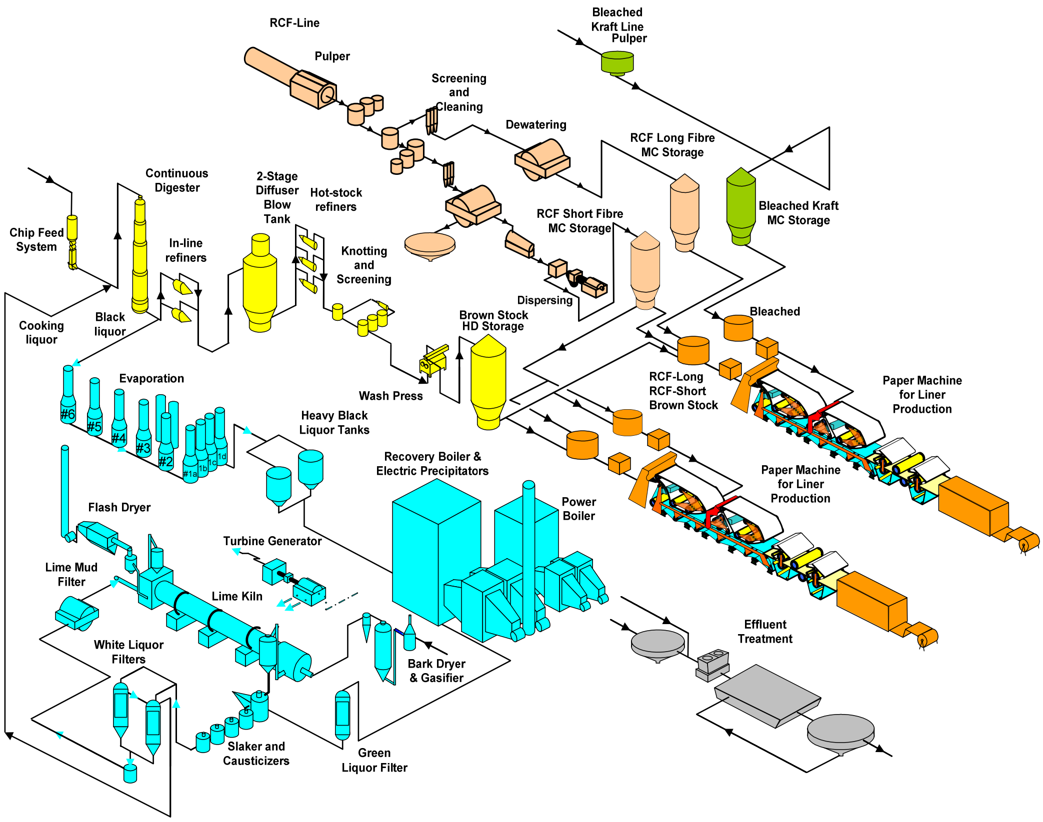

__Figure 6.1__ The reference kraftliner mill including the fibre line, chemical recovery, steam and power generation, liner machines, and effluent treatment.

6.3.1.1 Mill capacity and production

The kraft pulp mill has a capacity of 2000 ADt/d and a total liner production of 3100 t/d including recycled fibres and purchased bleached pulp.
All production data "at mill MCR", maximum continuous rate, refer to a production balancing the kraft mill MCR of 2000 ADt/d.

***Table 6.1** Summary of key operating data for the kraftliner mill*

Summary		**Reference mill**	**Type mill**
Wood to digester	t/24 h	3 221	1 610
Kraft pulp	ADt/24 h	2 000	870
Operating days	d/a	355	355
Mill availability		92 %	92 %
Annual production	ADt/a	653 200	284 100

Table 6.2 *Summary of key operating data for the recycled fibre plant*

Summary		**Reference mill**	**Type mill**
Pulp production, at kraft mill MCR	ADt/d	650	435
Yield	%	89	90
Annual pulp production	ADt/a	217 000	142 000

Table 6.3 *Summary of key operating data for the liner machines*

Summary		**Reference mill**		**Type mill**
		PM 1	PM 2	PM 1
Machine speed	m/min	1340	1230	1065
Width on pope	m	7.5	7.5	7.5
Grammage	g/m2	120 (80-200)	120 (115-200)	120 (115-200)
Fibre furnish				
Unbleached kraft pulp	%	67	59	67
Bleached kraft pulp	%	0	33	0
Recycled fibre (RCF) pulp	%	33	8	33
Consumption, at kraft mill MCR				
Unbleached kraft pulp	ADt/d	1097	903	870
Bleached kraft pulp	ADt/d	0	502	0
RCF pulp	ADt/d	548	100	435
Paper production, at kraft mill MCR	t92/d	1610	1473	1305
Annual paper production	t92/a	525 000	481 000	417 000

6.3.1.2 Fibre Line

The reference kraftliner pulp is made from 50 % pine (*Pinus sylvestris*) and 50 % spruce (*Picea abies*). The relation between roundwood and sawmill chips is 70 % roundwood and 30 % saw mill chips.

The debarking is performed in dry debarking drums with a closed re-circulation of sprinkling and de-icing water. A portion of the bark is gasified and utilised as fuel in the lime kiln; the rest is burned in the power boiler together with purchased bark.

6.3.1.3 Cooking

Cooking and delignification is performed in a continuous digester.

Wash liquor from the brown stock pulp wash goes to the digester, resulting in a dilution factor of about 2 m^3/ADt in the digester, including additional liquor added to the system from spills and leaks.

6.3.1.4 Screening, refining and washing

The pulp from the digester is refined in two parallel inline refiners. The refined pulp is washed in a 2-stage atmospheric diffuser washer and falls into the blow tank. After the blow tank, the pulp is further refined in three parallel hot stock refiners and then screened. The pulp is washed in three stages

- Hi-Heat washer in the digester,
- 2-stage atmospheric diffuser after the in-line refining,
- Final wash press after hot stock refining and screening.

6.3.1.5 Chemical Recovery

The chemical recovery and energy system have basically the same process solution as the market pulp mill, see section 3.1.

The steam production in the recovery boiler is not enough to meet the steam demand in the integrated kraftliner mill. A power boiler burning bark is therefore used to produce the required additional steam. The power boiler is designed with a bubbling fluidised bed (BFB) and produces HP steam.

About 60 % of the falling bark is burned in the power boiler together with purchased bark or other wood residues. Sludge from the effluent treatment is also burned in this boiler.

6.3.1.6 Recycled Fibre Plant

The raw material for the recycled fibre plant consists of old corrugated containers, OCC, which are delivered in bales.

After dewiring and bale breaking the paper is fed to a continuous high consistency drum pulper. It is then screened in three stages.

The pulp is fractionated into long and short fibre fractions. The fractionation reduces the investment cost as well as the operating cost of the plant as separate treatment of the fractions can be made.

The long fibre fraction is dispersed in a disperser plant. The first stage consists of a pre-heater that increases the temperature of the pulp to about 85 to 90°C by adding direct steam. The disperser treats the pulp mechanically so that hotmelts, stickies and other contaminants are dispersed.

The reject handling separates the various types of rejects and thicken them to a dry content that is suitable for the next step of the cycle, i.e. incineration, landfill or raw material for other processes.

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.

All substances that are dissolved in water in the process will be found in the wastewaters from the process. The amount of COD dissolved is very much dependent on the raw material for the recycled fibre. A normal range is 30-60 kg/ADt of COD in the waste water effluents. One of the most important factors for the amount of dissolved COD, is the starch content in the recovered paper.

6.3.1.7 Paper mill

To match the large capacity of the kraft pulp mill (2000 ADt/d), the most realistic option for the paper mill is to have two paper machines, referred to as PM1 and PM2.

- PM1 is aimed to produce 525 000 t/year of unbleached kraftliner, with up to 50 % recycled fibre in the base ply.
- PM2 is aimed to produce 487 000 t/year of white top liner.

6.3.1.8 Stock preparation

The bleached kraft pulp, purchased in bales, is slushed in pulpers, diluted to 4.5 to 5 % and stored in a storage tower. The pulp is then pumped to the pulp chest on PM2. There is a refiner between the pulp chest and the dosing chest.

The RCF long fibre pulp is diluted and then refined in a low consistency refiner before it enters the dosing chest. The refining improves the tensile and tear strength as well as the ply bond and increases elongation

Each ply has a set of mixing and machine chests. After the mixing chest there is a final consistency control to about 3 % before the machine chest.

6.3.1.9 Paper machine

The paper machines are based on a concept to allow for a high quality liner production at high machine efficiency and at a machine speed of up to 1500 m/min. Other important design data is presented in *Table 2.4.*

Table 6.4 *Summary of key operating data for the liner machines*

Summary		Reference mill		Type mill
		PM 1	PM 2	PM 1
Machine speed	m/min	1340	1230	1065
Width on pope	m	7.5	7.5	7.5
Grammage	g/m2	120 (80-200)	120 (115-200)	120 (115-200)
Fibre furnish				
Unbleached kraft pulp	%	67	59	67
Bleached kraft pulp	%	0	33	0
Recycled fibre (RCF) pulp	%	33	8	33
Consumption, at kraft mill MCR				
Unbleached kraft pulp	ADt/d	1097	903	870
Bleached kraft pulp	ADt/d	0	502	0
RCF pulp	ADt/d	548	100	435
Paper production, at kraft mill MCR	t92/d	1610	1473	1305
Annual paper production	t92/a	525 000	481 000	417 000

The base ply head box is of the cross profile dilution type. The top ply headbox is of conventional type.

The base ply and top ply former are gap formers to give the best paper uniformity with regard to formation, basis weight profile and sheet structure at these high speeds.

The press section is designed for optimum runnability of the machines by means of a closed web run from the wire section to the dryer section. A high dry content of the web leaving the press section is an important factor for the runnability of the press section. The press concept is two straight shoe presses. The final dryness after the press section is about 50 %. After the first press, a steam box increases the temperature of the web to increase dewatering. Another important feature of the steam box is to control the moisture profile of the final paper.

The first part of the dryer section is a single tier dryer, designed for high speed. The dryer is a combination of drying cylinders in an upper row and vacuum assisted rolls in a lower row

integrated with an air handling system including web stabilising equipment for increased runnability and minimum energy consumption.
The one-nip calender is of soft calender type to give optimum surface properties. The liner is finally winded up on the reel.

6.3.1.10 Energy systems and balance

Much effort has been devoted to the energy efficiency of the process concept, but also considering operability and payback. The key features of the energy system is the same as in the integrated fine paper mill.

6.3.1.11 Energy aspects for the paper machine

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.

6.3.1.12 Water system and balances

The mill is designed to have very low water consumption.. In addition to this there is also a consumption of water for cooling purposes in the mill. Almost all cooling is however made with a closed cooling system with the water circulating over a cooling tower, requiring only make-up to compensate for the evaporated water and a minimal purging to prevent build-up in the system.

The white water flow is counter-current from the liner machine to the RCF. Normally rejects are the only contaminated streams out from the paper machine.
The kraft pulp leaves the kraft mill at 30 % dryness. White water acts as pick-up water and dilutes the pulp to medium consistency before the MC-storage tower.
The only fresh water to the RCF plant is sealing water.
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.

6.3.1.13 Effluent treatment

Biological sludge will be dewatered to about 10 % in a centrifuge, mixed with deinking sludge and return fibre sludge and further dewatered on a screw press. This sludge will be incinerated in the bark boiler.
The water supply and treatment is basically the same as in the market pulp mill, see section 6.4.1.

6.3.2 Type mill, kraft liner mill

A typical mill will of course deviate from the reference mill in many ways. We will here only describe differences that affect the energy balance and the environmental impact. Most data in tables are already presented under the reference mill. General assumptions on the recovery and steam systems are the same as for the market pulp mill.
A summary of the changes is:

- Smaller size 870 ADt/d kraft pulp and only one paper machine, producing only unbleached liner.
- Continuous digester with conventional 2-flash system, no chip bin pre-steaming.
- Low consistency continuous pulper for shushing of recovered paper giving about 50 % higher energy consumption.
- Coarse screening of older type giving higher energy consumption and lower quality.
- No internal cleaning of white water with a DAF unit in RCF mill.
- The paper machine has two conventional fourdrinier wire sections giving higher energy consumption.
- The paper machine press section has only one shoe press giving lower dryness after press.
- The amount of recovered fibre is 50 % in the base layer.

6.3.2.1 Fibre line

The type mill has a “conventional” two flash digester and the pulp is washed on a diffuser and vacuum filters.

6.3.2.2 Chemical recovery

The deviations in chemical recovery from the reference pulp mill in the type mill are the same as for the market pulp mill, see section 3.1.

6.3.2.3 Recycled Fibre Plant

A typical RCF mill is rather old and some of the new techniques are not commonly used. The percentage of recycled fibre is set to 50 % in the base layer equal to the reference mill. Design capacity for the line is therefore 500 ADt/d.
The type mill RCF line has a conventional pulper with higher energy consumption. There is a simplified coarse screening, which results in a somewhat lower quality of pulp.
The RCF line has no internal DAF unit for white water cleaning which gives a higher need for counter current flow from the paper machine to maintain pulp cleanliness.

6.3.2.4 Liner machine

The type mill liner machine does not operate at speeds higher than about 1070 m/min. The production line has a lower production. Typical high production capacities for the paper machine is 417 000 t/a.
A typical wire section consists of two conventional fourdrinier sections. The base ply has a dilution control headbox. This type of forming sections need to have lower headbox consistency and thereby increases the energy demand for the mix pumps.
The press section has a double felted 1st press and a single felted 2 press followed of one shoe press. The outgoing dryness from the press section is approx. 47 %. More steam is therefore used for drying purposes in the paper mill.
The dryer section is a two tier dryer with drying cylinders in both an upper and a lower row.
The specific fresh water consumption is higher.

6.3.2.5 Energy systems and balances

The steam consumption in the type mill is higher than in the reference mill and more bark must therefore be burned in the bark boiler.

6.3.2.6 Water system and balance

The white water flow in the type mill is also counter-current from the liner machine to the RCF.
The kraft pulp leaves the kraft mill at 30 % dryness. White water acts as pick-up water and dilutes the pulp to medium consistency before the MC-storage tower.
The only fresh water to the RCF plant is sealing water.The effluent from the RCF plant is the treated water from the disc filter.

6.3.2.7 Effluent treatment

The differences in the effluent treatment for this type mill are mainly the same as for the market pulp mill, see section 6.4.1

6.4 *Integrated fine paper*

The Integrated Fine paper Mill also produces bleach market pulp.

6.4.1 Reference mill, bleached market pulp mill

The bleached kraft mill produces softwood and hardwood pulp in campaigns. The pulp mill is identical to the pulp mill in the integrated fine paper mill except for the dryer and paper machine parts.

The bleached kraft reference mill includes the entire pulp mill, from incoming wood to fully bleached and dried pulp. By-products that are sold are electricity, bark, tall oil and turpentine. Bleaching chemicals are purchased.
This reference mill is designed to produce fully bleached hardwood and softwood kraft pulp in campaigns, with the best available and commercially proven technology. The softwood is a 50/50 % mix of pine and spruce and the hardwood is birch with less than 10 % other hardwood species. (this is for the Nordic counties but varies depending on where the mill is situated).
The following general objectives and priorities for the mill have been defined:

- The mill shall be designed to have an optimum economy of scale.
- The pulp quality shall be consistent and competitive on the international market.
- The product is ECF pulp bleached without elemental chlorine.
- Specific consumption of wood, chemicals, energy and water shall be low.
- Environmental emissions shall be low, not give any significant negative impact.
- Process technology and equipment shall be proven.

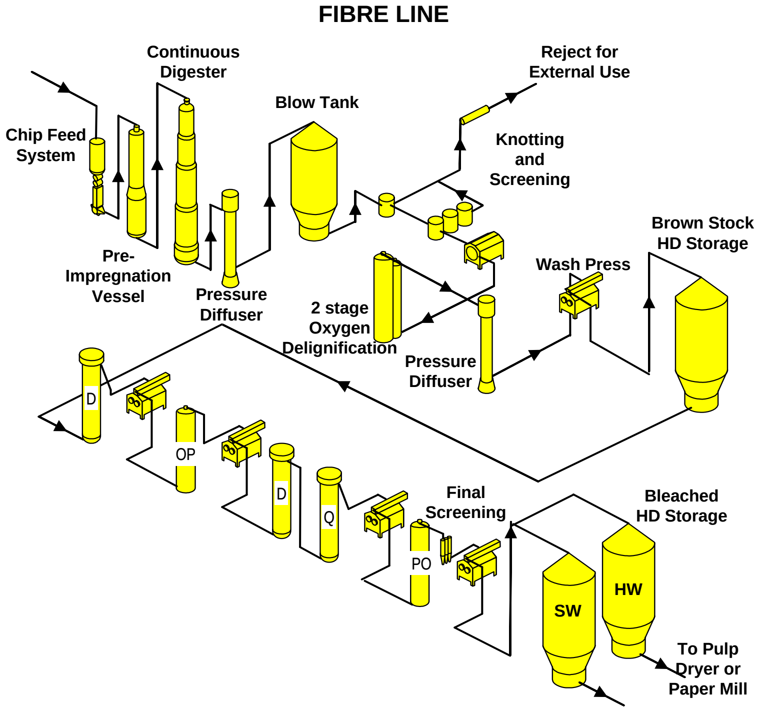

Figure 6.2 *Simplified flow sheet of the fibre line in the reference mill for bleached market pulp.*

The reference mill includes the fibre line, bleach plant, the pulp machine, recovery cycle and effluent treatment, see *Figure 6.2 and 6.3*

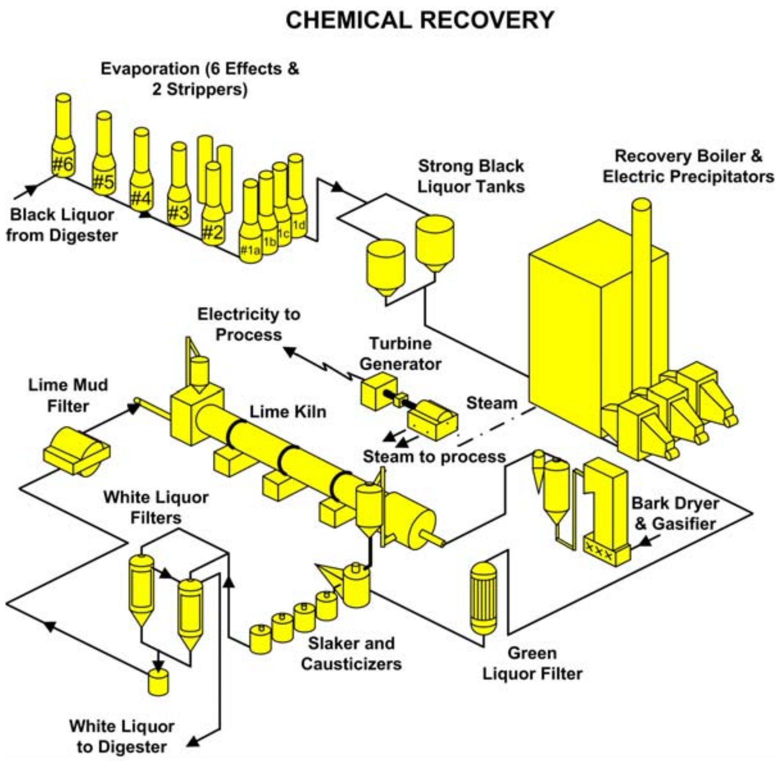

Figure 6.3 *Simplified flow sheet of the chemical recovery system in the reference mill for bleached market pulp.*

6.4.1.1 Mill capacity and production

Table 6.5 *Summary of key operating data for the bleached market pulp mill*

		Reference mill		Type mill	
Summary		**Softwood**	**Hardwood**	**Softwood**	**Hardwood**
Raw material:					
Wood to digester	t/24 h	4 148	4 610	2 065	2 328
Dried pulp from dryer	ADt/24 h	2 000	2 500	1 000	1 250
Operating days	d/a	355	355	355	355
Mill availability		92 %	92 %	92 %	92 %
Annual production	ADt/a	653 200	816 500	326 600	408 250

The needed capacities in the various departments are different when producing softwood and hardwood pulp. The capacity in the departments must therefore be adjusted so that the total capital cost for the combined production is minimised. The main difference is the higher yield of hardwood. This means that during softwood campaigns, the chemical recovery line will be limiting and during hardwood production the fibre line. For a one-line mill the dryer is the overall department that limits the capacity. With the present maximum width of 8 m a mill MCR production of about 2000 ADt/d for softwood and 2500 ADt/d for hardwood are about the maximum that can be achieved. With these productions the load on the recovery boiler will be about the same, maximising the utilisation of the recovery boiler.
The main operating data are summarised in Table 6.5.

6.4.1.2 Fibre line

Digester
Both continuous and batch digesting can be used. The batch processes, as marketed today however have higher steam consumption than the continuous process and thus the continuous cooking process is the main alternative in the reference mill.

Oxygen delignification
Oxygen delignification is done in two stages without intermediate washing to a kappa number of 10 for both softwood and hardwood.

Bleaching
The bleach plant is designed with four bleaching stages in the sequence D(OP)(DQ)(PO). Wash presses are used for all the washing in the bleach plant. The pulp is bleached to a final brightness of 90 % ISO.

6.4.1.3 Chemical recovery

Evaporation
The evaporation plant is a conventional 6-effect system utilising LP and MP steam. It is designed to produce 80 % dry solids liquor after addition of recovery boiler ash. To facilitate this, pressurised firing liquor storage is necessary.

Recovery boiler

The recovery boiler processes about 3400 tDS/d of black liquor for both softwood and hardwood, excluding recycled dust and biosludge. It is designed to produce high pressure steam at 80 bar(g) and 490°C. This results in a boiler that can be operated without any problems at the predicted potassium and chloride concentrations. The recovery boiler is also utilised to burn non-condensable gases.

Causticising
The reference mill is equipped with a conventional causticising plant with both green liquor and white liquor filtration.

Lime kiln
The lime kiln is equipped with an external lime mud dryer and modern product coolers. The kiln is fired with fuel gas from a bark gasifier.

6.4.1.4 Energy systems and balance

Some key features in the energy system are:

- No power boiler, the mill is self-sufficient in both steam and power
- Lime kiln fired with gasified bark, surplus bark sold
- Back-pressure turbine to cogenerate electric power.
- Condensing turbine, to generate power from excess steam.
- Recovery boiler steam data, 80 bar(g), 490ºC .
- High feed water temperature and low flue gas temperature in recovery boiler.
- Low-pressure steam used in the pulp dryer.
- Pressurised condensate system
- High temperature of the hot water, 85ºC, and maximum use of hot water instead of steam in the bleach plant, pulp machine and boiler feedwater heating.

The result is a mill that is self-sufficient in steam and power.

Table 6.6 *The steam data in the market pulp reference mill are:*

	Reference mill		**Type mill**	
Steam data	°C	bar(g)	°C	bar(g)
HP-steam	490	80.0	450	60
MP-steam, desuperheated	200	9.0	200	10
LP-steam, desuperheated	150	3.5	150	3.5

6.4.1.5 Water system and balance

The process water consumption is low, by closed systems in most mill areas. All of the evaporation condensates are reused. Wash presses in the bleach plant contribute to low water consumption.
Almost all cooling water and excess warm and hot water are recovered and recirculated over cooling towers. The exception is minor amount of water from oil coolers, because of risk for contamination.

6.4.1.6 Effluent treatment

Effluent treatment is designed for hardwood campaigns and comprises pre-treatment (cooling equipment and neutralisation) and biological treatment. Even though, a primary clarifier is foreseen as security to take care of accidental fibres from process. Primary sludge will be dewatered in a centrifuge and sold to fluting mill or similar.

6.4.2 Type mill, bleached market pulp mill

A typical mill will of course deviate from the reference mill in many ways. We will here only describe differences that affect the energy balance and the environmental impact.
A summary of the differences is:

- Lower production, 1 000 ADt/d vs. 2 000 ADt/d for reference mill.
- HP-steam data 60 bar and 450ºC
- No steam surplus, a bark fired boiler provides necessary steam
- No condensing turbine
- Back-pressure turbine too small, part of the steam directly reduced
- Lower efficiency for turbine
- Continuous digester with conventional 2-flash system, no chip bin pre-steaming.
- Alkali charges in digester considerably higher than in the reference mill
- One stage oxygen delignification
- Evaporation plant stage wise expanded and operating with 5.5 effect economy, 72 % DS.
- Lime kiln fired with oil
- Bleaching with conventional ECF, R10 ClO_2 plant
- Minor steam consumption for heating, woodyard and causticising assumed.

6.4.2.1 Fibre line

Digester
The various continuous digester concepts available today are very energy efficient. Many existing mills however still use the old "conventional" two-flash digester. The loading of the digester is also normally raised over the years and therefore also the temperature is higher than in new digesters.

Bleach plant
The ECF bleach sequence in the type mill uses much more ClO_2 and less H_2O_2 than the reference mill
The bleach plant is a little more open than in the reference mill, which together with the higher wash water flows needed for filters results in about twice the effluent from the bleach plant compared to the reference mill.

6.4.2.2 Chemical recovery

Evaporation
The evaporation plant has the advantage that it can easily be expanded in small steps by adding new evaporators. Earlier most evaporation plants were built with five effect economy. After increasing the evaporation plant many mills therefore has a combination of five and six effect economy. For the type mill it is assumed that the evaporation plant in average operates with 5.5 effect economy. The strong liquor from the evaporation plant is 72 % and only LP-steam is used for the evaporation.

Stripper
A stripper for the evaporation plant is nowadays standard, but has not always been. Many strippers today are therefore not fully integrated in the evaporation plant, some are completely separate, and some recover the steam partly in the evaporation plant.

Lime kiln
The lime kiln is fired with oil.

6.4.2.3 Energy system and balance

Bark boiler
With the higher steam consumption in the type mill, steam production from the liquor is not sufficient and a power boiler fired with bark is necessary. There is no bark press and the bark is fired at 40 % dryness.

Steam turbine
The typical mill has increased the production over the years with debottlenecking measures and the steam turbine has consequently become too small to take care of all steam. Part of the HP-steam must therefore be reduced directly to lower pressures by pressure reducing valves, PRVs. The efficiency of the turbine is also lower than for modern turbines, due both to wear and less original efficiency. When the mill was originally built there was no steam surplus from liquor and falling bark and no condensing turbine. The typical mill today has a steam surplus from liquor and falling bark, but needs part of the bark to produce the required steam. The type mill therefore use as much bark as needed in the bark boiler and sells the bark surplus.

6.4.2.4 Steam and power balance

The type mill is self-sufficient in steam from liquor during softwood campaigns, with a slight surplus that is blown off as LP-steam to maximise power generation. During hardwood campaigns there is a need for more steam and this is produced by burning bark in a bark boiler. The lime kiln is oil fired. The surplus bark is sold.

6.4.2.5 Water system and balance

The type mill has higher water consumption than the reference mill, mainly due to the bleach plant configuration.

6.4.2.6 Effluent treatment

Effluent treatment for this type mill is a low loaded activated sludge plant with selector. The selector could be aerated or not aerated (anoxic). One purpose to choose anoxic selector is if chlorate removal is needed. The treatment comprises pre-treatment (cooling equipment and neutralization), primary treatment and biological treatment. Suspended solids level in mill effluents are normally higher than in the reference mills and therefore primary treatment is an important stage and primary sludge amounts will be higher than in the reference mill.

6.4.3 Reference mill, integrated fine paper mill

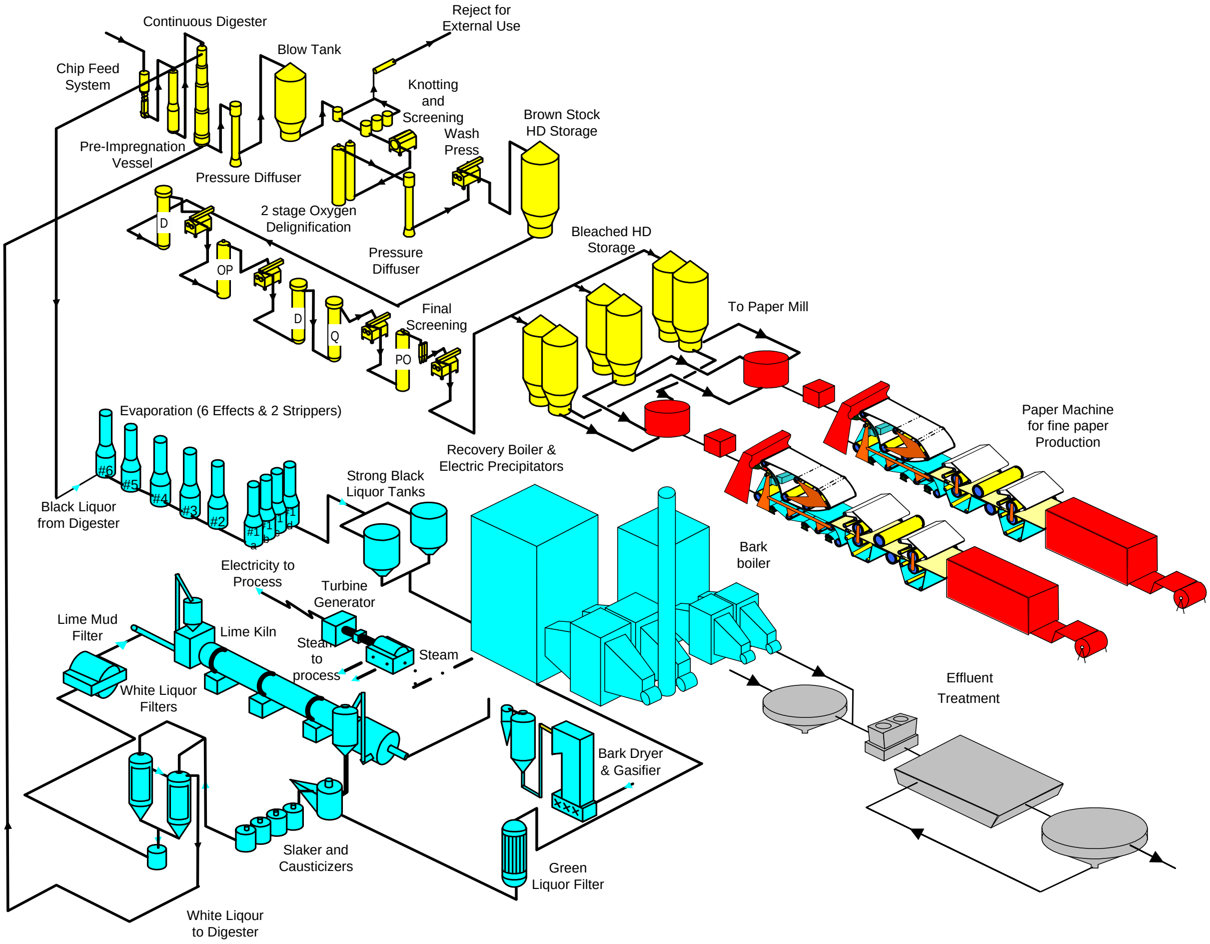

Figure 6.4 *The reference fine paper mill including the fibre line, recovery area, steam generation, bleach plant and the fine paper machines.*

6.4.3.1 Pulp mill

The pulp mill in the integrated fine paper mill is the same as in the market pulp mill described in section 3.1.

The steam production in the recovery boiler is however not enough to meet the steam demand in the integrated fine paper mill. A power boiler burning bark is therefore used to produce the required additional steam. The power boiler is designed with a bubbling fluidised bed (BFB) and produces HP steam.

The falling bark not used in the lime kiln is burned in the power boiler together with purchased bark or other wood residues. Sludge from the effluent treatment is also burned in this boiler.

6.4.3.2 Paper mill

To match the large capacity of the kraft pulp mill, the most realistic option for the paper mill is to have two paper machines, referred to as PM1 and PM2. Both PM1 and PM2 produce uncoated fine paper from softwood and hardwood. Each paper machine has an annual production of 511 000 t/a.

The calculations show that the integrated fine paper mill is approximately self-sufficient in steam consumption whereas a third of the power consumption must be bought.

A simple block diagram for PM1 and PM2 is shown in *Figure 6.5*.

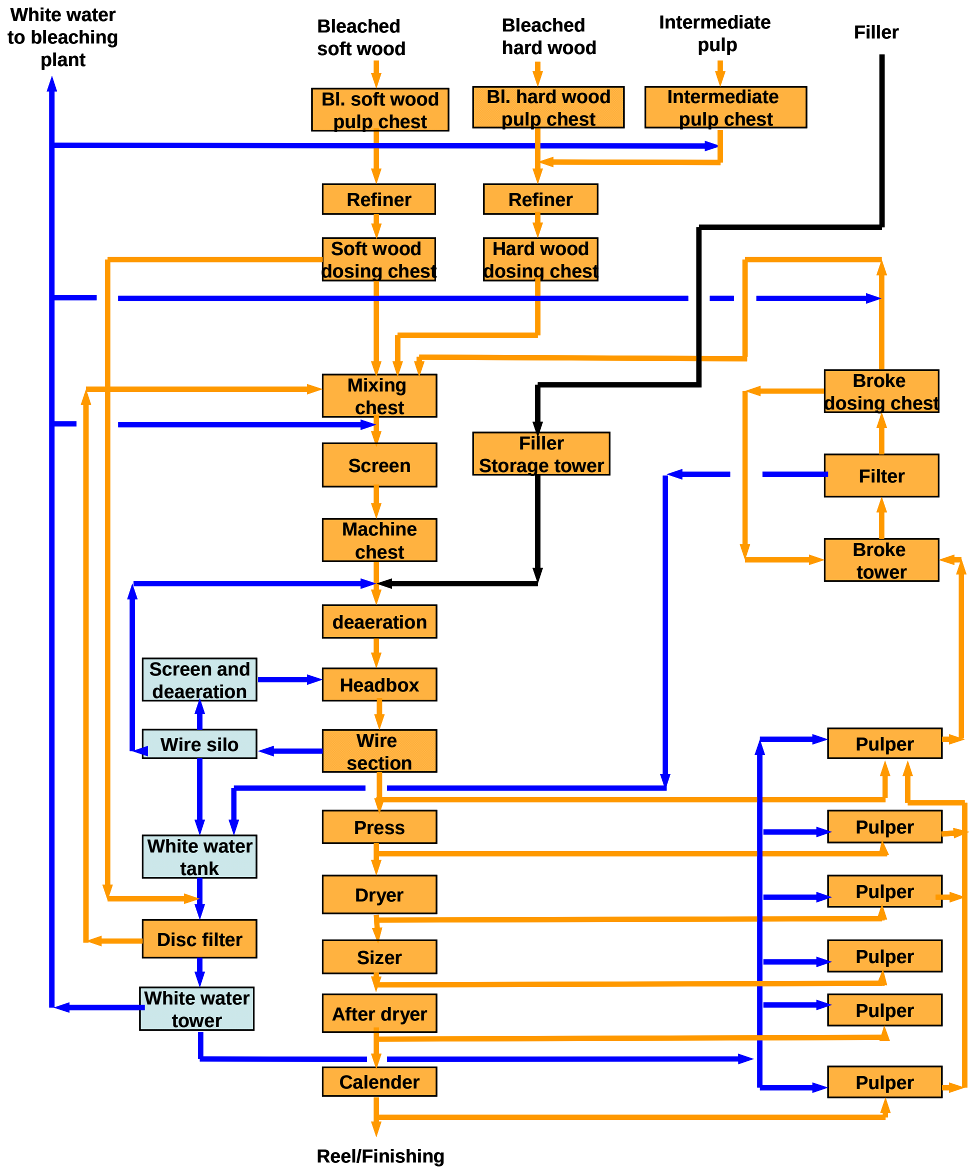

Figure 6.5 *Block diagram showing the process concept of the reference fine paper machines.*

6.4.3.3 Stock preparation

Bleached hardwood and softwood are diluted after their respective MC-storage tower and pumped to the pulp chests. Hardwood and softwood can be refined separately to optimise their properties. The pulp mill produces softwood and hardwood in campaigns of 30 h and 70 h respectively. Since there is not a perfect plug-flow through the pulp mill, there will be some intermediate pulp produced when changing from hardwood to softwood. This intermediate pulp is stored in a MC-tower and added to the paper macine furnish in a controlled way.

6.4.3.4 Paper machine

The paper machine is based on a concept to allow for a high quality fine paper production at a high machine efficiency and high speed. The paper machine is dimensioned for 1850 m/min.
The wire section is a modern twin wire section to give the best paper uniformity with regard to formation, basis weight profile, ash profiles and sheet structure.
The press section is designed for optimum runnability of the machine by means of a closed web run from the wire section to the dryer section.
The dryer section consists of a pre-dryer section and an after dryer section. The pre-dryer section is a combination of drying cylinders in an upper row and vacuum assisted rolls in a lower row

integrated with an air handling system including web stabilising equipment for increased runnability and minimum energy consumption.
The sizer after the pre-dryer section is adding surface size to both sides of the web by means of an application roll system to increase strength properties of the paper.
The calender is of soft calender type in a tandem arrangement to give the optimum surface properties.
Main data for PM1 and PM2 are presented in the table below which also includes data for the type mill machines:

Table 6.7 *Main data for PM1 and PM2 of the integrated fine paper mill*

		Reference mill		Type mill	
		PM 1	PM 2	PM 1	PM 2
Machine speed	m/min	1690	1690	980	980
Width on pope	m	9.0	9.0	7,8	7.8
Grammage	g/m2	80 (75-160)	80 (75-160)	80 (75-160)	80 (75-160)
Production on pope (100 % eff.)	ADt/h	73	73	37	37
Paper dryness	%	93	93	93	93
Fibre furnish					
Hard wood , Birch	%	56	56	56	56
Soft wood	%	19	19	19	19
Filler	%	25	25	25	25
Surface size of paper (starch)	%	3	3	3	3
Consumption, at kraft mill MCR					
Hard wood pulp	ADt/d	877	877	440	440
Soft wood pulp	ADt/d	292	292	147	147
Annual consumption					
Hard wood	ADt/a	573 000		287 000	
Soft wood	ADt/a	191 000		96 000	
Filler	BDt/a	235 000		118 000	
Starch	BDt/a	27 600		13 800	
Paper production, at kraft mill MCR	t93/d	1 565	1 565	785	785
Annual paper production	t93/a	511 000	511 000	256 000	256 000

6.4.3.5 Energy systems and balances

The balances are presented as separate balances for hardwood and softwood, representing steady state production for each of them. In a real mill the campaigns will mean that the balance will be varying between the softwood and the hardwood case depending on the campaign length.
The mill is very energy efficient and black liquor and falling bark are sufficient to produce the energy needed for process steam consumption and cogeneration of power in the back-pressure turbine. The back-pressure power generation is not enough and additional power must be bought. A minor amount of bark surplus is sold.

6.4.3.6 Energy aspects of the paper machine

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.

6.4.3.7 Water system and balance

The mill is designed with a very low water consumption. The total fresh water used in the processes is below 20 m^3/ADt. In addition to this there is also a consumption of water for cooling purposes in the mill. Almost all cooling is however made with a closed cooling system with the water circulating over a cooling tower requiring only make-up to compensate for the evaporated water and a minimal purging to prevent build-up in the system.
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. Warm water is received from the kraft mill. The paper machine white water system consists mainly of a white water tank for paper machine excess water connected to a disc filter save-all. Clear filtrate from the disc filter is used for shower purpose in the wet end and is also stored in a white water storage tower to be used for consistency control and for broke dissolving. The surplus clear filtrate is pumped to the bleach plant.
A correct dimensioning and use of the storage buffer volumes also mean minimal variations in the flow of waste water to the external treatment plant which should result in higher cleaning efficiency and lower investment and operating costs for the external treatment plant.

6.4.3.8 Effluent Treatment

The effluent treatment is the same as described for the market pulp mill in section 6.4.1.

6.4.4 Type mill, integrated fine paper mill

6.4.4.1 Pulp mill

The pulp mill is the same as in the market pulp mill and the deviations from the reference mill are the same, see section 6.4.1.

6.4.4.2 Paper machines

The type mill fine paper machine does not operate at speeds higher than about 1000 m/min. The production line has a lower production. Typical high production capacities for the paper machine is 255 000 t/a.
The paper machine forming section is of hybrid type i.e. an initial fourdrinier forming followed by twin-wire forming, giving higher energy consumption.
The approach flow system is equipped with cleaners and is therefore more power consuming than the reference mill which have a “guard screening” system.

The press is a four-nip press section with a steam box before the fourth nip
The water consumption is higher thereby giving a higher cost for heating.
The stop times are longer for maintenance thereby giving lower availability.
The dryer section is a two tier dryer with drying cylinders in both an upper and a lower row.

6.4.4.3 Energy system and balance

The mill is energy efficient and black liquor and falling bark together with a minor amount of bought bark are sufficient to produce the energy needed for process steam consumption and cogeneration of power in the back-pressure turbine. The back-pressure power generation is not enough and additional power must be bought.

6.4.4.4 Water system and balance

The type mill has a higher water consumption than the reference mill mainly due to the bleach plant configuration. The process water consumption is about 35 m^3/t paper compared to about 18 m^3/t paper in the reference mill.

6.4.4.5 Effluent treatment

Effluent treatment for this type mill is the same as for the market pulp mill; see section6.4.1.

7 Processing and manufacturing –solid wood chain (Arto Usenius, Jorma Fröblom)

7.1 Description of the sawmill processes for the Scandinavian Case study

7.1.1 Background

The solid wood test chain; describing sawn timber, edge glued panel/boards and solid wood chair production and also power and pellet production from pine logs or stems (Scots pine, *Pinus sylvestris*); is situated in Scandinavia.

Principal system description
Normally in Scandinavian countries solid wood chairs are produced from timber blanks/components and/or edge glued panels/boards.

Timber blanks/components are produced in sawmill. Edge glued panels/boards are produced from sawn timber in own production unit or at furniture factory. Chair factory are using blanks/components and edge glued panels/boards for producing- solid wood chairs.

Pine wood raw material enters to the sawmill producing sawn timber and in some cases component type of products as well. A part of sawn timber is used in the production of edge glued products providing raw material to the manufacturing of pine chairs. There are two main categories of raw materials to be used in the chair production: sawn timber and edge glued timber. Both of these raw materials are converted in the different machining phases into components. In the assembling phase the final product is formed.

Chair factory is normally only one customer to the sawmill or glued panel factory. The raw material suppliers have to sell their products to other customers as well. Of course the chair company may have several raw material suppliers.

In all manufacturing processes - sawmill, panel factory and chair factory - side products are received: bark, chips, sawdust, shavings, off cuts. Depending of type of side products the final destination may be: pulp and paper factory, chip board factory, own heat and power production, bio-energy pellets etc.

In the following pictures material flow and the production systems are generally and more in detail described.

7.1.2 Wood products – Model Processes

7.1.2.1 Timber Production Processes - Today and Future Processes

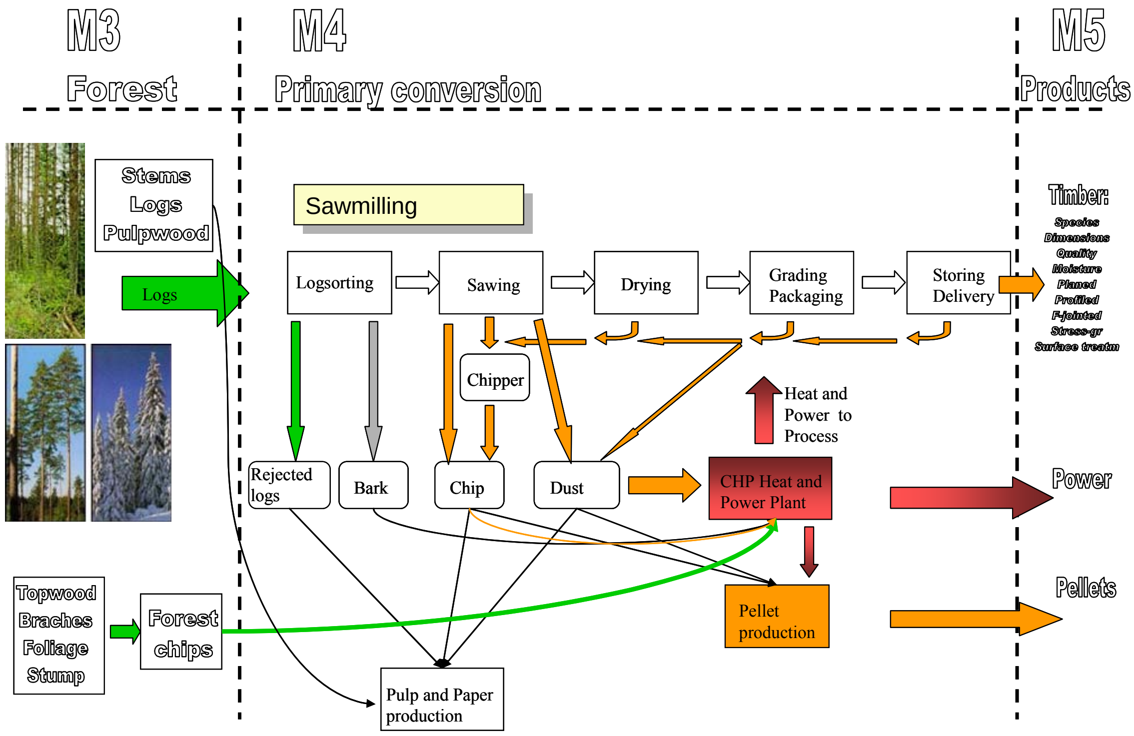

Figure 7.1 *General timber process steps.*

7.1.2.2 Harvesting

Wood species to be exploited are Pine and Spruce. Harvesting operation produces wood raw material in form of stems and logs. The option is that the stems are transported to the mill because this offers excellent possibilities for optimisation of raw material allocation. In the later phases in the processes there are not possible to correct the failures mad in cross cutting of stems. If the stems are longer than 18 m, the tops of the stems are cut into the logs in the forest.

7.1.2.3 Cross cutting of stems

Stems are transported from the forest to the mill. Shape and x-ray scanning of stems provides data of geometry and internal properties i.e. knots of stems and logs. Scanning result of individual stems is transferred into optimisation software systems calculating most profitable crosscutting procedure based on order file and demand profile of the desired products.

7.1.2.4 Sorting of logs

Sorting station is estimated to consist of 40 – 100 bins. Number of bins is enough for avoiding resorting of logs. Tight log classification supported by internal log characterization allows almost “individual sawing approach”. Allocation of sorting bins is depending on the product demand. Following categories are considered.

1. saw logs to be sawn normally with fixed sawing set-up without any major set up changes between logs
2. length sorted saw logs – specific length requirements
3. saw logs which are sawn individually cut by cut with specific sawing system into high value added products

Sorting of logs is based on products or sawing set-ups. Quality of the logs – internal characterization-is the main criteria in the sorting operation. Sorting optimization software calculates best possible sawing. A sorting bin consists of log to be processed with the same set up which means higher capacity in the sawing line.

The optimal positioning i.e. rotation orientation of the log is marked with line on the top end of the actual log. The line is marked with ink jet writer. The logs can also be individually marked i.e. using RFID technology. The marking provides an address in the data base in the information system controlling overall sawing process from the cross cutting terminal to the final end products. Behind the address stem / log properties, sawing set-up options and corresponding output is estimated. Sorted log batches are stored on the log yard.

7.1.2.5 Sawing operation

Following requirements are set to the sawing system

1. Flexibility to realize sawing of small logs and bigger logs – top diameter range from 10 cm to 45 cm
2. Flexibility to adapt different types of product – from bulk products to components with specific requirements
3. Flexibility to execute batch based sawing with fixed sawing set up in order to minimise the caps between logs or to saw logs on individual bases.
4. Capability to maximise quality properties of logs produced by advanced scanning. This means that
    - the sawing set up can be freely changes according to the log properties
    - rotation and positioning of the log and cant are in proper control
    - the outer parts (best parts) of the log are fully exploited – sawn timber pieces can be taken also far from log sides
5. Saw kerf is as narrow as possible
6. Sawing accuracy, standard deviation of dimension is excellent
7. Technical quality of sawn timber is good
8. Electricity consumption is low
9. Control system is open
    - can receive control data from other information systems
    - can produce and transfer information back to the other information systems

- provided by friendly human technology interfaces

The sawing system may consist of one or two sawing lines operating in three shifts, five days a week.

For sawing of big logs and high quality logs a special sawing system is used. System is based on single cut approach. Just before sawing operation the log is scanned producing accurate shape and quality information. Optimisation software system creates the log model. Based on the log model and product demand, optimisation software calculates the position of next cut and orientation of top and butt ends of the log yielding maximum value yield. After the execution of the cut the surface characteristics of opened face are recorded. Based on this information new log model and next optimised cut is determined. Repeating this procedure the sawing of log is value optimised. Some parts of the log i.e. thick flitches or cants can be transported to multiple re-saw and or cross cut saw in order to make value added components.

Sawing system should support control system based on identification of pieces based on marking technology.

7.1.2.6 Handling of wet sawn timber pieces

After sawing operations sawn timber pieces are transversal transported. Just after sawing there is scanning system for detecting quality features of all four sides of the piece. Extra information i.e. annual ring orientation can be received through scanning of ends of timber pieces. Based on scanning information the individual timber members are addressed to the tray sorting layer or sorting bin. Use of sorting system is optimised through software. Tray sorter provides carefully handling of pieces and possibility to optimise the material flow.

Dimensions, lengths and especially quality and properties of sawn timber members determine the drying program. Scanning results information for “collecting” right pieces into right bins and further to drying.

7.1.2.7 Drying of sawn timber

The design values for kiln drying are 10 – 12 % and to 16 – 18 %. For these purposes can be used progressive kilns and batch kilns.

The most significant areas which has to be taken into account when choosing kiln are to achieve the target moisture content (MC) and minimise or limit MC gradients and to minimise or prevent distortion of pieces during drying and in service conditions.

The deformation which occurs in sawn timber during and after the drying process is the most important reason for down grading timber during primary processing.

The deformations that occur during and after drying are related to the characteristics of the raw material (e.g. grain angle, density, juvenile wood content, compression wood, knots), kilning schedules and technologies, and post kilning conditioning treatments. Many properties to avoid this can be measured from logs and green timber.

The final moisture content of a piece of dried timber and its uniformity throughout the section is regulated by the drying process. The moisture content of the timber can influence dimensional changes that occur when in use. Excessive dimensional changes can be avoided if the timber has been dried to a moisture content similar to that which it will attain when in use.

Splits and checks which occur on timber surfaces after drying is a common result of intensive kiln drying. These can be avoided with correct drying schedules.

Drying will also affect the final colour of the timber, higher temperatures resulting in darker colouration. Drying will also affect the behaviour of knots and flow of resin in coniferous timber.

7.1.2.8 Final sorting and packaging

After drying sawn timber pieces are transported transversally. Final sorting station is provided by scanning system for detecting quality features of all four sides of the piece. Annual ring orientation can also be measured. Based on scanning and length information the individual timber members are addressed to s specific sort or channelled to the dry mill.

In the final phase on manufacturing sawn timber is packaged.

7.1.3 Reference Sawmill

A sawmilling industry can be described if you like as 6 capacity levels. Each level has certain amount of sawmills and these are forming a region's or country's Sawmilling Industry.

Table 7.1 *Example of the capacity classes of region/country sawmilling industry*

Capacity classes	<200 000	200 000	150 000	100 000	50 000	10 000
Nr of sawmills	19	7	10	22	34	2094
Logs (Mean value of log use)						
Pine	273761	231946	88500	73497	25039	497
Spruce	348587	165007	181900	79799	39174	360
Total	622348	396953	270400	153295	64213	857

The sawing capacity of the reference mill is about 200 000 m3. Chips are sold to pulp industry. Sawdust is used for producing pellets. Pellet production is about 20 000 tn. Consumption of heat and power in pellet production is about 4,5 MW. Sawmill has its own heat and power plant (CHP). In CHP plant is used bark and forest chips for heat and power production.

Each capacity class has its own reference mill.

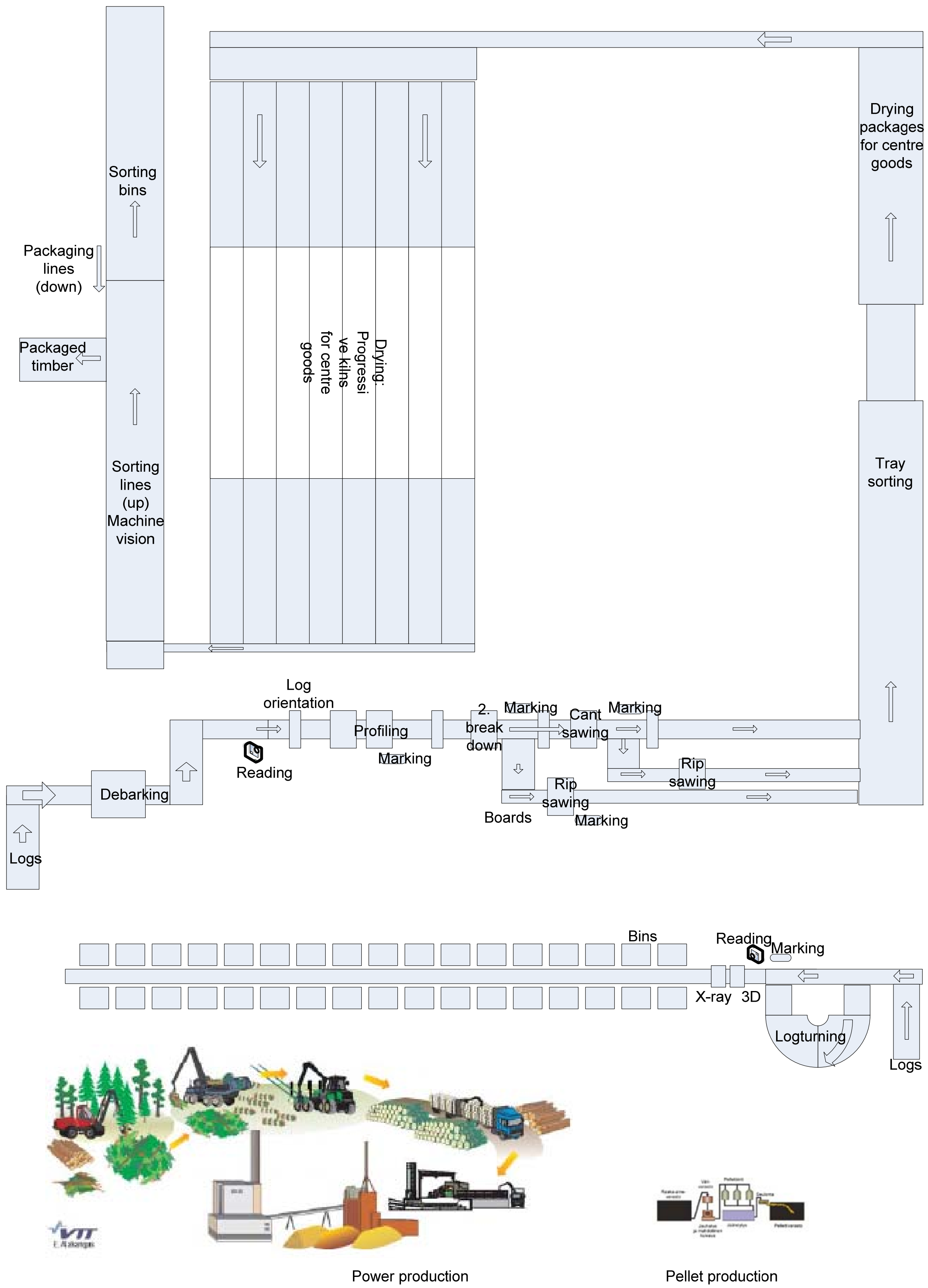

Figure 7.2 *Principal layout of timber production process including power and pellet production.*

Table 7.2 *Summary of the operating data of reference sawmill (example)*

Capacity class	200 000	m3
Nr of sawmills	1	
Logs (Mean value of log use)		
Pine	450 000	m3
Spruce		
Total	450 000	m3
Harvesting		
Stemwood (final felling)	300	m3/ha
logs	270	
pulpwood	30	
Biomass	90	m3/ha
Topwood	4	m3/ha
Sawing/by-products		
Bark	44 000	m3
Chips	92 000	m3
Sawdust	48 000	m3
Economical and social indicators		
Labour force	60	pcs
Machinery	23	m€
Buildings	9,5	m€
Electricity	100	kWh/m3
Heat	350	kWh/m3
Prices		
Bark	8	€/m3
Chips	10	€/m3
Sawdust	35	€/m3
Log price	54	€/m3
Unit costs in harvesting	6	€/m3
Unit costs in long-distance transport	6	€/m3
Production Costs		
Labour costs	9	€/m3
Wood raw material costs	66	€/m3
By-products	52	€/m3
Operating costs	39	€/m3
Capital costs	23	€/m3
Product price at factory	190	€/m3

7.1.4 Edge Glued Panel/Board Production – Model Processes

7.1.4.1 Production Processes - Today and Future Processes

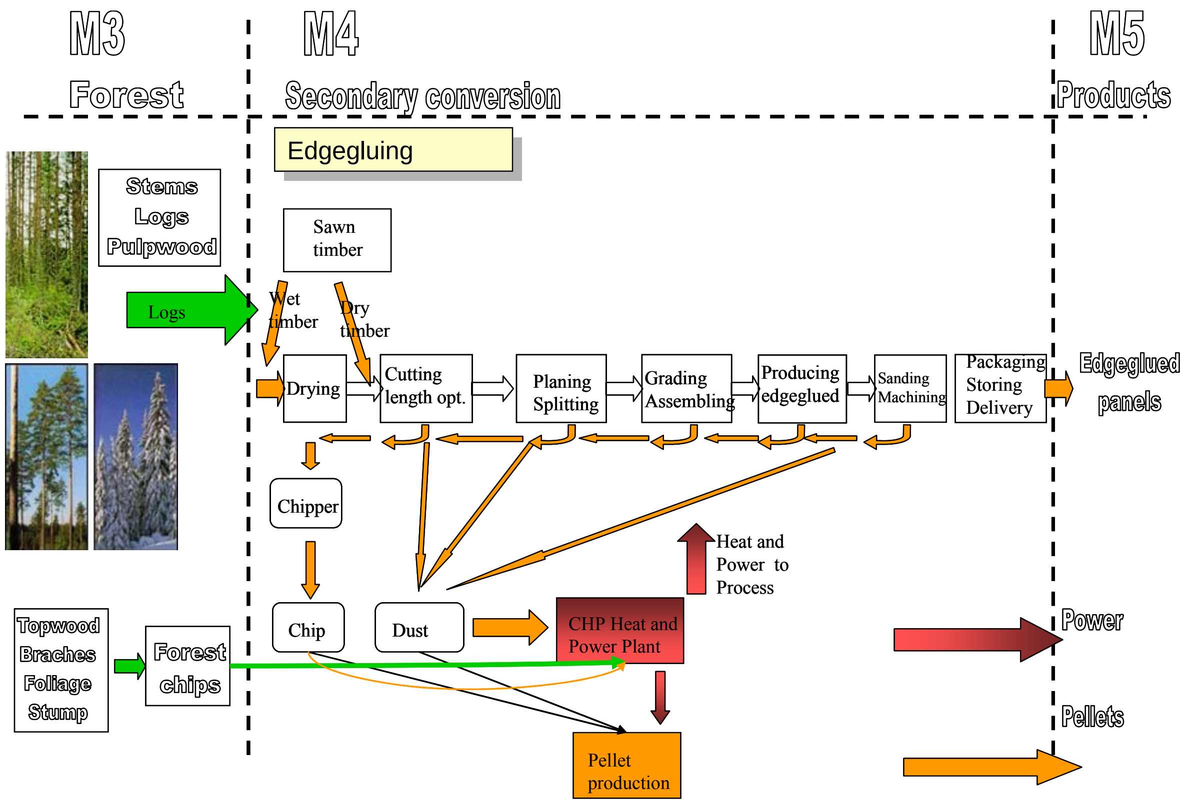

Figure 7.3 General edge glued panel/boards production process steps.

Edge glued panels/boards are an important component of many high quality furniture designs. Edged glued panels/boards may be used for exposed furniture parts (such as doors), furniture boards, table- and kitchen worktops, work bench boards, stair-treads/steps, stair-strings, handrails and risers, cheek boards, construction boards, shelf bottoms, door-casing- and door-frames, window-sills.

7.1.4.1.1 Drying (option)

Procedure of wood drying is given 2.1.6 drying of sawn timber.

The timber must be dried to moisture content appropriate for the environment of its intended end-use (8±2% for most of European countries). The timber must be equalized to insure the moisture content is uniform, and conditioned to eliminate drying stresses in the timber which may result in warped panel components when the timber is cut into parts. Also the moisture content must be maintained during wood storage and manufacturing process.

7.1.4.1.2 Machining of Panel/Board Components

The scanner device can be used in optimising cross cutting saw lines and in quality grading after planing machines, where wood is being graded.

Dried sawn timber is machined in planing machine. Machining is done either planing first or splitting then or vice versa. Both are done in same planing machine and same time. Machined parts must be straight, have parallel and square edges, and surfaces of good quality, otherwise it may result in cupped panels and joint failure.

7.1.4.1.3 Gluing and Pressing

Glue quality and spread levels should be regularly monitored. Supervisors should observe clamp operators to assure operators are attentive and visually check glue spreads on each component. Pressure levels, cycle times (stand time and press time), and conditioning times should be monitored.

The construction of the hot pressing needed when handling urea glues and the strength of the friction press. This allows pressing both hard and soft wood types.

The press consists of two parts but it operates on continuous basis: the “hot area” of the front part activates the glue quickly and decreases the pressing time dramatically. The back area of the press is a cooling area, from which the board slabs are moved to further processing. The glue applicator allows up to 300 m/min feeding speed for the laths. Also smaller quantities can be processed; it takes less than one minute to change the linear measure of the board.

Press can be used as part of an automatic edge gluing press line.

- Variable glue interruption in through feed direction for production of panels with variable dimensions
- Multi-line processing of short work pieces
- Optimum utilization of the pressing section and increased flexibility for product dimensions
- Product-oriented joint pressure adjustment
- Processing of soft- and hardwood
- Option: Cross-cut saw, dividing and milling saws

Special cutting devices can been used in cutting framework components, splitting glued components in connection with the edge gluing press and in the front and at the back of planer for dimensioning the components.

7.1.4.2 Reference Edge Glued Panel/Board mill

A edge glued panel/board industry can be described if you like as 6 capacity levels. Each level has certain amount of mills and these are forming a region's or country's Edge glued panel/board Industry.

Table 7.3. *Example of the capacity classes of region/country Edge glued panel/board industry*

Capacity classes	<20 000	20 000	15 000	10 000	5 000	1 000
Nr of mills	2	2	2	3	10	20
Timber (Mean value of timber use)						
Pine						
Spruce						
Total						

The Edge glued panel/board capacity of the reference mill is about 24 000 m3. Sawdust and chips is used for producing pellets. Pellet production is about 12 000 tn. Consumption of heat and power in pellet production is about 3 MW.

Each capacity class has its own reference mill.

Table 7.4. *Summary of the operating data of reference mill (example)*

Capacity class	24 000	m3
Nr of mills	1	
Timber (Mean value of timber use)		
Pine	58 000	m3
Spruce		
Total	58 000	m3
Edge gluing and by-products		
By-products	34 000	m3
Economical and social indicators		
Labour force	48	pcs
Machinery	3,5	m€
Buildings	2,9	m€
Electricity	120	kWh/m3
Heat		kWh/m3
Production Costs		
Labour costs	64	€/m3
Wood raw material costs	140	
By-products	86	
Operating costs	71	
Capital costs	32	
Product price at factory	390	

7.1.5 Solid Wood Furniture Production – Model Processes

7.1.5.1 Production Processes - Today and Future Processes

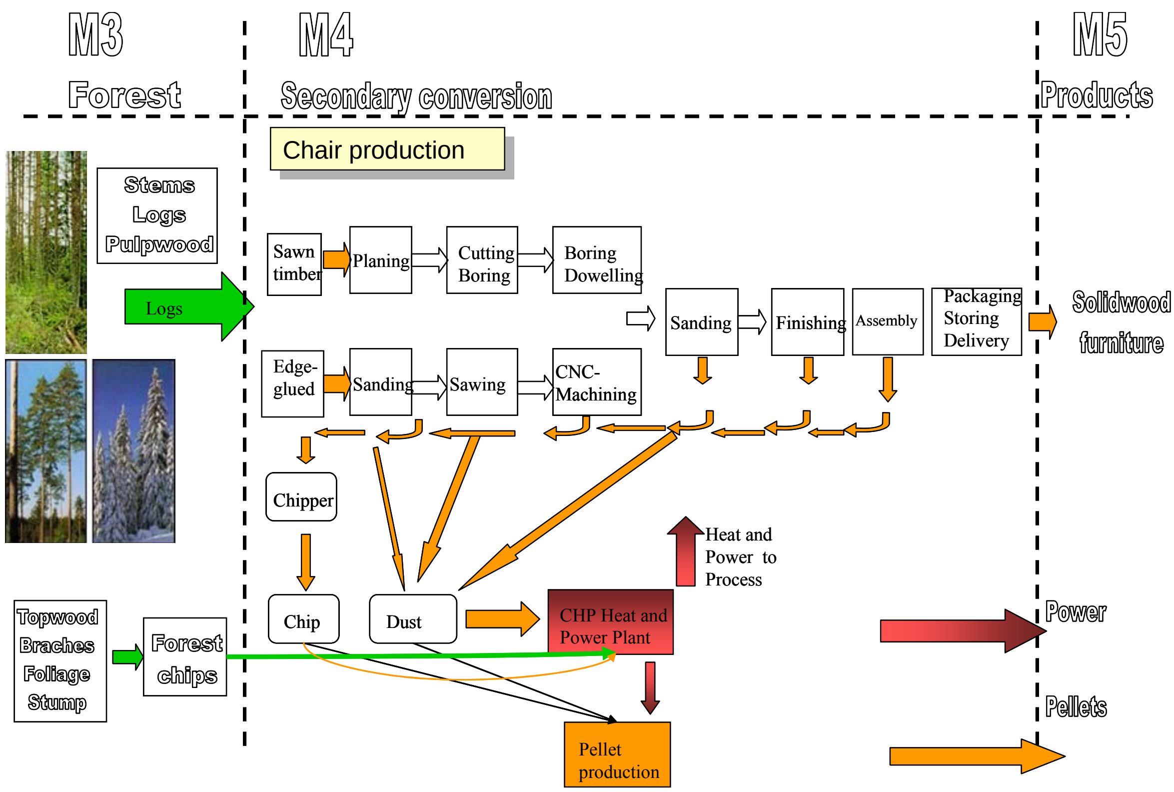

Figure 7.4 *Description of chair production.*

7.1.5.2 Reference Furniture production

The EU furniture industry is a market and product oriented industry using a large variety of materials. Material innovation has become a crucial part to maintain one of the major strengths of the sector: its product development and design capabilities. 45% of total production value consists of purchase of specific raw materials or semi-finished products by the furniture industry from other manufacturing industries.

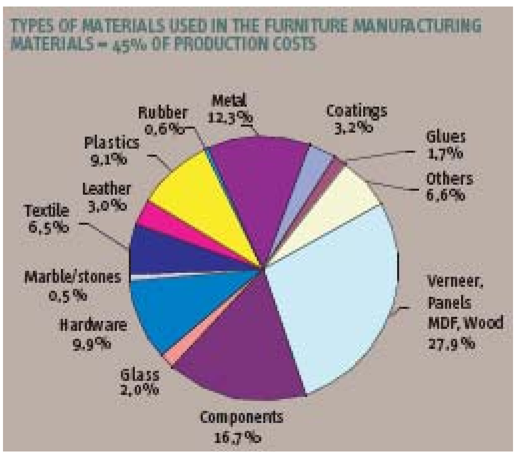

Figure 7.5 *Source: European Furniture Manufacturers Federation*

According to cost structure wood furniture production can be divided in following categories: 1) solid wood furniture, 2) bent wood furniture (solid/veneer), 3) wood panel/board furniture, 4) cushioned furniture and ~~5) mattresses~~. Raw material costs, labour costs, costs of machinery, building and energy and operating costs differs some in each category.

Perhaps reference mills have to be done to these categories. On the other hand statistics can be found easier in the categories mentioned in table 4.28.

Table 7.5 *Summary of the operating data of reference mill (example)*

	Chairs and seats	Office- and shop fittings	Kitchen	Other furniture	Mattresses
Turn over/person	135	123	145	115	
Operating revenue	100	100	100	100	
Material costs	46,4	46,8	45,6	45,6	
External costs	3,2	4,8	12,1	5,0	
Labour costs	23,6	26,6	22,1	26,2	

8 Industry to consumer (to be completed in next stage)

9 Time schedule

The following time schedule has been agreed in the Implementation plan for month 13 to 30. The task force needs to ensure that these deadlines are met.

Major milestone	Short description	Targeted Time of delivery (month)
Case study	Definition of regional cases studies completed	18
FWC data-base	Information related to regional cases completed	24
ToSIA – FWC	The basic version of ToSIA, tested at regional cases' level	24

To meet the given deadlines the following steps are followed:

M2 meeting in Barcelona During week 7. The collected preliminary forest data will be discussed	February 2007 - M 2 meeting in Barcelona
M2 reports back from the Barcelona meeting on decisions taken on forest resource/stand identification to M3-M5.	Within a week after Barcelona meeting
M3 allocation meeting in Uppsala week 10. M3 identifies the most relevant harvesting and logistic systems to "transfer" the wood from the forest suitable for the identified forest stands	after Uppsala meeting
M4 and M5 start a review on wood industry, and wood consumption, volumes produced and consumed with the origin of Vaesterbotten	
M4 and M5 identify the most relevant partial chains for each sector (wood, fibres, bioenergy)	end of March 2007
Telephone meeting to discuss proposed chains	Week 12 March 23 2007
M2, M3, M4, M5 refine definition of case study Scandinavia, agree on data and information structure and transfer	March to April 2007
Telephone meeting to discuss proposed chains	Week 18 May 4 2007
Final definition of case study (boundaries, chains and processes identified, data structure and interfaces agreed)	May 2007, Eforwood week
Report describing the forest-based Scadinavian case study	June 2007 PD 2.0.3 - month 20
Updated report on Scandinavian case study	December 2007 PD 2.0.5 – month 26