EFORWOOD
Tools for Sustainability Impact Assessment

Collection and aggregation of single chain data from WP 3.1-WP 3.4 in order to derive ToSIA inputs in commonly agreed units and formats and deliver those to M1

Diana Vötter, Staffan Berg, Lars Wilhelmson, Volker Bölle and Arnaud Villette

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Preface

This report is a deliverable from the EU FP6 Integrated Project EFORWOOD – Tools for Sustainability Impact Assessment of the Forestry-Wood Chain. The main objective of EFORWOOD was to develop a tool for Sustainability Impact Assessment (SIA) of Forestry-Wood Chains (FWC) at various scales of geographic area and time perspective. A FWC is determined by economic, ecological, technical, political and social factors, and consists of a number of interconnected processes, from forest regeneration to the end-of-life scenarios of wood-based products. EFORWOOD produced, as an output, a tool, which allows for analysis of sustainability impacts of existing and future FWCs.

The European Forest Institute (EFI) kindly offered the EFORWOOD project consortium to publish relevant deliverables from the project in EFI Technical Reports. The reports published here are project deliverables/results produced over time during the fifty-two months (2005–2010) project period. The reports have not always been subject to a thorough review process and many of them are in the process of, or will be reworked into journal articles, etc. for publication elsewhere. Some of them are just published as a "front-page", the reason being that they might contain restricted information. In case you are interested in one of these reports you may contact the corresponding organisation highlighted on the cover page.

Uppsala in November 2010

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EFORWOOD

Tools for Sustainability Impact Assessment

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Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	x
RE	Restricted to a group specified by the consortium (including the Commission Services)	

Collection and aggregation of test chain data from WP 3.1-WP 3.4, in order to derive ToSIA inputs in commonly agreed units and formats and deliver those to M1

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Date: 20th August 2007 (first draft)

Summary/Purpose of the report:

This deliverable is meant to give an overview as well as be a means of look-up list, on used assumptions, calculation modes, used models and delivered data for a restricted set of indicators for the test chains within the EFORWOOD project.

This document is entirely only about the TEST CHAINS and data we delivered for them. The case studies and with them the single embedded chains will come later, namely in Month 27, Jan 2008.

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1 Introduction

1.1 Use and importance of indicators in EFORWOOD

The aim and output of EFORWOOD and its tool ToSIA is described on the webpage as: "The aim of the project is to provide methodologies and tools that will, for the first time, integrate Sustainability Impact Assessment of the whole European Forestry-Wood Chain (FWC), by quantifying performance of FWC, using indicators for all three pillars of sustainability; environmental, economic and societal. "

For the assessment of the European Forest-Wood Chain (FWC) it is of prime interest to have a holistic approach on selecting criteria and indicators in the context of EFORWOOD Module 3 ("Forest to Industry Interactions"). For this reason EFORWOOD concentrates on the three pillars of sustainability, integrating the multiple benefits of forest resources at an economic, social and environmental level (KIRKPATRICK and GEORGE, 2005).

Thus the first step for a sustainability impact assessment is the collection and calculation of adequate criteria and indicators. Criteria and indicators have been developed to describe and help monitor progress in achieving sustainable forest management through several international, regional and national commissions and fora. Therefore they were applied at several Ministerial Conferences on the Protection of Forests in Europe (MCPFE 2002), such as in Strasbourg 1990, Helsinki 1993, Lisbon 1998, Vienna 2003 and the upcoming conference in Warsaw 2007. Also the European Union has adopted sustainable development indicators in 2005 (compare EUROPEAN COMMISSION 2005).

In ToSIA, only the term "indicator(s)" is used and those indicators can, according to TRASOBARES et al (2007) "in a generic sense (…) be viewed as factors or variables that can be used to measure the status and change of a system or process. Indicators permit operationalising the concept of sustainability. The use of indicators allows for deconstructing of the sustainability assessment problem into manageable bits that can lend themselves to more formal or structured analysis (MENDOZA and PRABHU, 2002). Indicators for SIA can be quantitative (€, tons of C, person hours) or qualitative. Qualitative indicators can be converted to ordinal scale (e.g., the naturalness of a forest stand can be classified as 1=natural, 2=semi-natural, 3=planted)" (compare EFORWOOD DELIVERABLE D1.4.3).

1.2 Used set of indicators

Indicators, which will be used for the calculation in ToSIA, have been collected in an iterative approach, resulting in several Draft sets of indicators. Currently EFORWOOD Indicator Draft Set 5 and the related module-specific indicators are in repeated discussion.

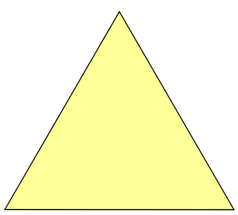
As the data collection for the test chain had already started earlier on, and as this data collection was designed first of all as a learning exercise, only a reduced set of 12 indicators was identified. That was the 4th Draft set of indicators, and thereof from the set of Lead indicators some were selected by Marcus Lindner, M1, and called "ToSIA Lead indicators".

Those were the following:

Number	**Indicator with its subclasses**
(1)	LI 1 Gross Value Added
(2)	LI 2a Production cost of process inputs from the FWC

	LI 2b Other production costs
(4)	LI 4a Resources and material use (wood material)
	LI 4b Resources and material use (non-wood material)
	LI 4c Resources and material use (recovered raw material)
(10)	LI 10a Employment male
	LI 10b Employment female
	LI 10c Employment rural
	LI 10d Employment urban
(11)	LI 11a Wages and salaries male
	LI 11b Wages and salaries female
(12)	LI 12a Occupational accidents (non-fatal)
	LI 12b Occupational accidents (fatal)
	LI 12c Occupational diseases
(13)	LI 13a Education time per person-year working time in the process
	LI 13b Education expenditure per person-year working time in the process
(15)	LI 15a Energy generation (from process inputs)
	LI 15b Energy generation (from other wood biomass)
	LI 15c Energy generation (renewable)
	LI 15d Energy generation (non-renewable)
	LI 15e Energy use/ share self-sufficiency
(16)	LI 16b Carbon sequestration in woody living biomass (above and belowground)
	LI 16c Carbon sequestration in woody dead biomass (standing and lying), RESIDUES
	LI 16d Carbon sequestration in forest soils
	LI 16e Carbon sequestration in harvested wood products
	LI 16a Total greenhouse gas emissions per process
(17)	LI 17a Transport distance road transport
	LI 17b Transport distance rail transport
	LI 17c Transport distance water transport (inland waterways and sea)
	LI 17d Transport distance air transport
	LI 17e Freight volume road transport
	LI 17f Freight volume rail transport
	LI 17g Freight volume water transport (inland waterways and sea)
	LI 17h Freight volume air transport
(18)	LI 18a Water use in total
	LI 18b Water pollution with organic substances
	LI 18c Water pollution with nutrients
	LI 18d Water pollution with hazardous substances

Figure 1 explains which part of which version had been used for data collection on test chain level. Data presented in this deliverable only refer to this set, as only test chain data is described in this deliverable.



Draft set 1 (February 2006)

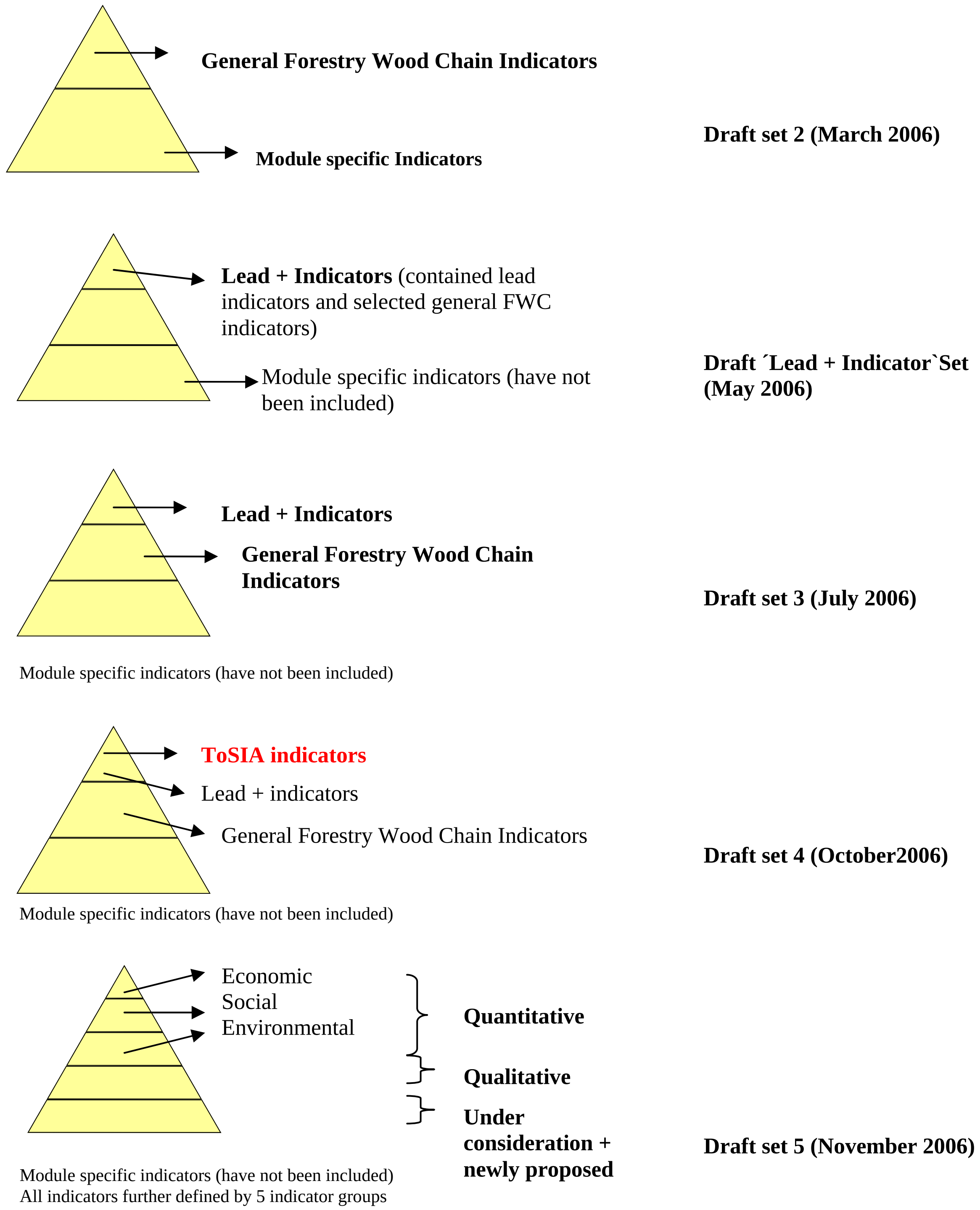


Fig 1:

At the IP Board (11) during the EFORWOOD autumn week 2006 in Lisbon, Portugal on November 14-15, 2006, it had been agreed to use the 5th set of General indicators for the embedded single chains, case studies and the European study, comprising the following indicators:

Economic indicators	8	Indicator No: 1 to 8
Social indicators	4	Indicator No: 9 to 12

Environmental indicators	10	Indicator No: 13 to 22
plus:		
Qualitative indicators	6	Indicator No: 23 to 28
Under consideration	1	Indicator No: 29
Newly proposed	2	Indicator No: 31 to 32
In sum:	31	

From the 5th Set of indicators onwards, there is no more distinction made between Lead+ and General indicators; only between General indicators, which are calculated for the whole chain, and module-specific indicators, which are calculated at module level.

Furthermore, it had been agreed that a set of module-specific indicators shall be collected module-wise until the end of January 2007. Those and their integration shall be discussed during the next EFORWOOD spring week 2007 in Zvolen, Slovakia.

Result of the test chain data collection exercise however, was the formation of indicator expert groups for environmental, socio-economic, transport, energy and waste indicators. These groups have been working on definitions, calculation methods and system boundaries of each indicator of the IP Board approved set 5 of General indicators. Those results have also been presented, discussed and agreed upon during the following EFORWOOD spring week 2007 in Zvolen, Slovakia.

1.3 Status quo, difference test chain – single chain

In the first planning phase of the project, the development of the modelling of the Forest Wood Chain was supposed to be carried out in three steps:

1. at test chain level; for the
    a. Pine chain
    b. Spruce chain
    c. Eucalypt chain
2. at case study level; for the
    a. Scandinavian (Production) Case
    b. Baden-Württemberg (Regional) Case
    c. Iberian (Consumption) Case
3. at European study level

During the first year of EFORWOOD and the work on test chain data collection the decision was taken that the test chains should in a second step be developed further into so-called "embedded single chains" (Single Chains, in short). Those single chains will serve two purposes:

a) They will be embedded into the case study, making up one strand of possible alternative chains or strands within the case study.

b) They will be calculated with the entire set of General indicators and module-specific indicators.

This document, however, concentrates on data collection and aggregation within Module M3, namely the work packages WP 3.1 to 3.4 for the Test Chains. Furthermore, inputs in commonly agreed units and formats will be provided as they have been delivered to M1.

2 Main part – data material

2.1 Pine test chain

2.1.1 Set up of test chain

The work on single chains is a simplified approach for later stages. For this reason only one stand with two alternatives was modelled for M2 (“Forest Resources Management”) output product. These stands were treated with regeneration measures, pre-commercial thinning, one thinning and one final harvesting. The characteristics of the stands were pragmatically chosen as a representative condition for forest operations in Västerbotten (NUTS SE081) on Pine stands, predominantly situated in the coast land.

	Stocking [stems/ha]	Cutting [stems/ha]	volume	Cut volume	DBH [cm]	Stem volume [m^3sub]
Pre commercial thinning**	1500	1000	3 m^3ob	1 m^3ob		
Thinning	900*	320	130* m^3sub	55 m^3sub	15,9	0,17
Final harvesting	500	500	180 m^3sub	180 m^3sub	21,2	0,36

Tab 1 Basic stand characteristics for stand harvested in Single FWC Scandinavian Pine chain

*Staffan Berg´s calculation

**E-mail from Tomas Lämås 18 June 2007. Standing volume with branches (Marklund, 1988) 3,75 m^3ob of which 1,25 left on ground.

The operation consists of the felling of undesired trees. They are left on the ground. 3,75 m3 ob; 2,81 m3 sub biomass/ha. 1,25 thinned and left at site. The conversion factor is referred to m^3sub with branches with the anticipation that bark content is 25% (PS 1994 page 260). Carbon content per cubic metre wood and bark alike is assumed to be 0,215 to C/ m^3ob

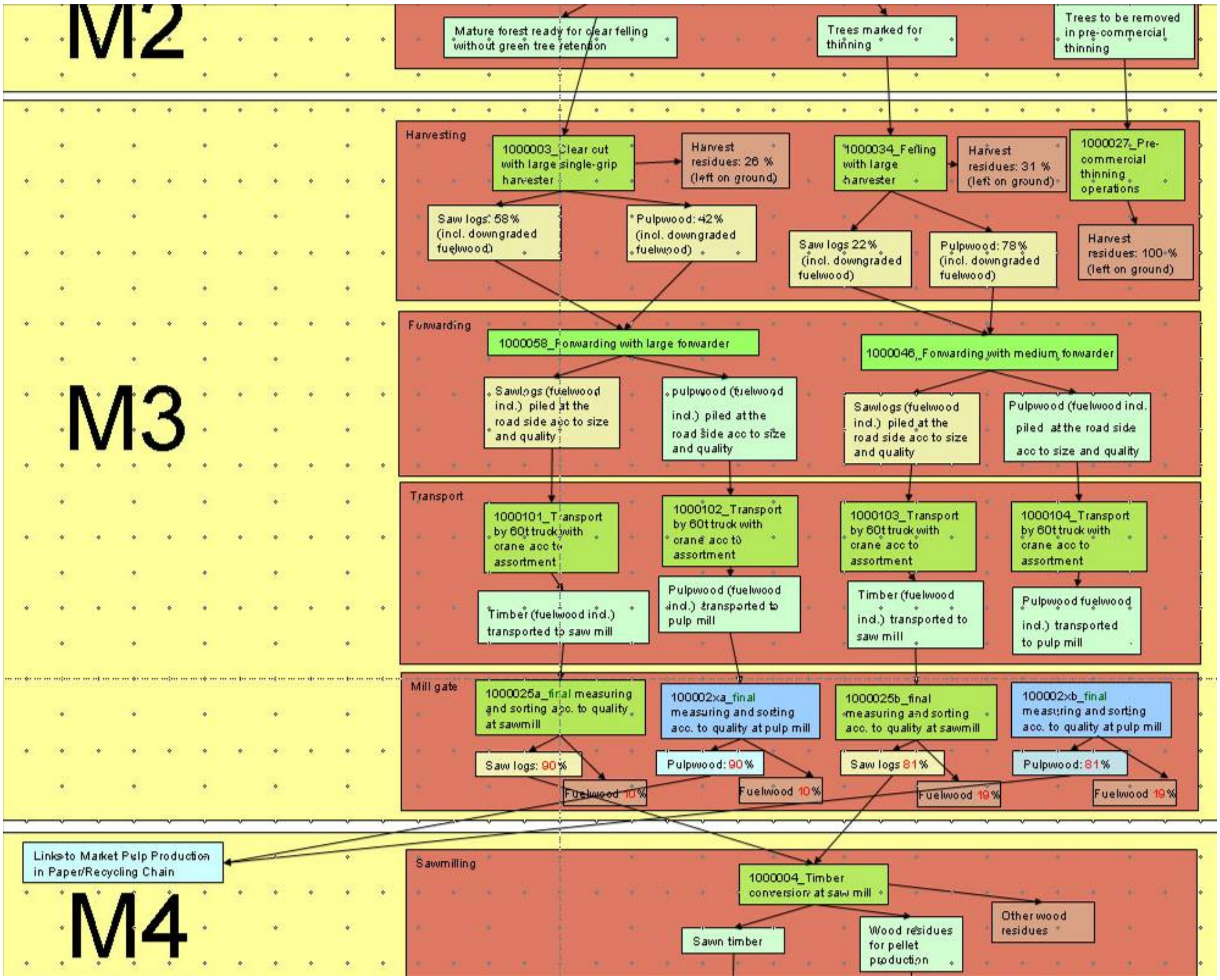


Fig 2: M3 part of the Pine test chain with input from M2 and output to M4.

The chain of operations is described in Figure 2. Pre-commercial thinning of planted pine stand in young phase, (Process ID 1000027), is done with the motor manual brush saw. The small trees cut (The harvest residues) are left on ground in order to maintain the productivity of the stand (Table 1 and 3).

Thinning (Process ID number 1000003) and forwarding (Process ID number 1000046) was calculated as a fully mechanized approach, creating sawlogs and pulpwood for delivery to industry (M4 – "Processing and Manufacturing"), whereas harvest residues were left as biomass (21%) on the ground and not further followed during subsequent processes.

The thinning gave 22% sawlogs and 78% pulpwood of the industrial wood.

Final harvest of the mature pine stand is also performed by completely mechanized procedures, similar in design as thinning, Process ID 100003 and 1000058 for final felling and forwarding respectively. The final felling gave 58% sawlogs and 42% pulpwood. Branches and tops (23%) were left on site.

In the Scandinavian Pine chain from both thinnings and final fellings only sawlogs were followed as a product to industry (saw mill and pulp mill). The timber is transported by road vehicles. The average distance for transport of saw logs were 93 km and this is described by Process ID 1000101 and 1000103, transport by road vehicles after thinnings and final felling respectively.

The sawlogs are loaded at road side after forwarding and unloaded at the sawmill. The same performance is anticipated for driving, loading and unloading of logs after thinning for timber.

	Product ID	Tons/year delivered at millgate
Saw timber inclusive fuelwood final felling	2021100	4102523
Saw timber thinning	2041100	575555
Pulp wood inclusive fuelwood final felling	2021101	2970792
Pulp wood thinning	2041101	2040603

Tab 2 Raw material delivered Single FWC Scandinavian Pine chain

The measuring of sawlogs at industry is done by one person who operates at the timber reception at the saw mill and its operation, except manpower cost, 0,29 Euro/m^{3}sub, is paid by the mill and will so be covered by M4.

2.1.2 Models for calculation

The modelling for calculation of machine costs and the way of describing forest operations is described in Eforwood deliverable "D3.2.3. SI-data for harvesting operations based on 3.2.1 and 3.2.2". The cost calculation is made according to the excel-based routine "Cost calculations.xlc" (Eriksson & Berg, 2007). Time functions for harvesters and forwarders are according to Brunberg (1995, 1997 and 1998).
AFOCEL set the basis for transport process calculations, using the excel-based file "Transport-cost-Paris.xls", as well as the model "Procou" (PD3.3.2).

The excel-based model "Transport-cost-Paris_Martins svar 061004.xls" was developed based on PD 3.3.2 by Afocel/Skogforsk; the cost estimates for road hauling is calculated. The result is presented in Table 3. The industrial wood is delivered at industry, Table 6.

The conversion factors (tab 7 and tab 8) have been calculated in two steps.
Table 7 originates from a preliminary bucking simulation using Skogforsk-TimAn (Ogemark & Arlinger, 2003) by a standard price list (reflecting the common price relations between different kinds of sawlogs and pulpwood) of trees from sample plots growing in the coastland of Västerbotten and Norrbotten (1996-2000). Measured (diameter (bh) height and age) by the National Forest Inventory of Sweden (SLU). The bark thickness was estimated by functions (Hannrup, 2004) while fresh weights and carbon contents were calculated by mean values from national forest statistics.
Table 7b show the results from the second step. In this case a selection of plots from the National Forest Inventory (2001-2005) reflecting different kind of stands (mature for final cut or thinning) growing in the county of Västerbotten (Valinger et al. 2007) were used as a basis for the bucking simulation. In this case the bucking simulation was performed as described above but in addition further analysed by the tool Skogforsk-Pri-analyses (examples of first Eforwood analyses are given in Wilhelmsson et al. 2006). In this analysis the fresh weights were predicted by models (Wilhelmsson & Moberg, 2004) requiring an input of the number of annual rings in cross-sections of log ends provided by a model (Wilhelmsson, 2006). These predictions have been made to improve the property values of different assortments and growth conditions of the actual trees. Finally the carbon contents were predicted by a tentative model (Wilhelmsson,

unpubliced), based on findings by Lamlom & Savidge (2003) and predictions of basic density (Wilhelmsson et al. 2002).

2.1.3 Calculation modes

Operations in Single FWC Scandinavian Pine chain

Entity	value	ref
Person hours/ha	9,4	Skogforsk data bank
Person hours/ha, male	8,5	SSY 2005, Tables 7,7; 12,3 and 12,5
Person hours/ha. female	0,9	SSY 2005, Tables 7,7; 12,3 and 12,5.
Person hours/ha, urban*	7,7	SSY 2005 tables 7.7 and SYS Table 03
Person hours/ha. rural	1,7	SSY 2005 tables 7.7 and SYS Table 03.
Labour cost/ personhour	19,50	Cost calculation. xlc
Energy cost/ha	18,3	Skogforsk model
Total cost /ha	217	Skogforsk model

Tab 3 Characteristics of pre commercial thinning in Single FWC Scandinavian Pine chain

*Urban population is people outside populated centres**
** At least 200 inhabitants and distance between houses less than 200 m

Investment. Euro	2 000
Depreciation, years	4
Interest rate %	4,0
End value, Euro	0
Repayment factor	0,275
Investment, Euro/year	**551**
Staff salary, Euro/hour	11,2
Social costs and taxes, %	40,00
Working days / year	210
Working hours / shift	8
Overtime, Euro/h	20,0
No. Shifts/day	1
E0/E15	0,75
Travel to Work, km/day	50
Travel to Work, Euro/km	0,3
No. of moves (sites) / year	19
Standstill per move, hours	3
Working hours/year	1 680
E15-h/year	1 203
Travel to work, km/year	21 000
Staff costs	
Salaries Euro/year	18 766
Travel to work, Euro/year	6 479
Social costs and taxes/year	7 506
Per day allowance, euro/year	0
Sum	**32 751**
Operating costs	

Diesel, Euro/l	1
Oils, Euro/l	3
Diesel consumption, l/E15-h	2
Oils consumption, l/E15-h	0,2
Repair & maintenance, euro/E15-h	1
Fuel costs, Euro/year	2 406
Oils, Euro/year	722
Repair & maintenance, Euro/year	602

Tab 4 Some input for pre-commercial thinning in Single FWC Scandinavian Pine chain according to Cost calculation.xls

FFH= Final felling Harvesting; FFFW=Final felling Forwarding; TH=Thinning Harvesting; TFW =Thinning forwarding

		FFH	**FFFW**	**TH**	**TFW**	**References and equivalent**
Investment 1000 €	€	330	309	330	255	Skogforsk expertise
Depreciation	years	4	7	4	7	1 year for motormanual equipment, 4 years for harvester, 7 years for forwarders and skidders
Interest rate	%	4	4	4	4	4% based on Euro market 6 months bonds 2001 - 2006 + 1,9 %
End value	€	49,5	123,4	49,5	102	
Administrative costs, insurance and miscellaneous	€/PMH	6,51	5,87	6,53	5,91	allocated per PMH. According to cost models, se ref.
Social costs and taxes	year	25879	25879	25879	25879	for labour, According to cost models, se ref.
Taxes machine		-	-			
Machine Hours	PMH/year	3975	4479	3915	4419	productive machine hours, PMH According to cost models, se ref.
Moving costs	€/PMH	0,96	0,85	1,99	1,77	allocated per PMH, According to cost models, se ref.
Labour cost	€/PMH	26,00	23,10	26,40	23,40	excluding taxes and social costs
Infrastructure costs	€/ m^3	-	-	-	-	costs for infrastructure roads and terminals allocated per m^3
Total Costs per PMH	€/PMH	88	61	90	59	
Productivity/	m^3sub/PMH	22,8	15,3	11.1	14,3	According to time functions, see below
Fuel use	l/PMH	16,1	14,6	16,1	11	Diesel oil, 0,820 kg/m3 MK1 (www.agrol.se)
Use of lubricants	l/PMH	0,8	0,45	0,8	0,45	Biogradable lubricants, 1,2 kg/m3 (www.agrol.se)
Use of	kg/PMH	0	0	0	0	

chemicals						
Fuel cost	€/l	1	1	1	1	incl. taxes, According to cost models, see below
Lubrication cost	€/l	3	3	3	3	incl. taxes, According to cost models, see below
Cost for chemicals	€/kg	-	-	-	-	incl. taxes, According to cost models, see below
Cost for maintenance	€/PMH	17	8	17	6,5	includes repair, tyres, According to cost models, see below.

Tab 5 Characteristics of machine operations in Single FWC Scandinavian Pine chain

Supporting data files:
Tidsfunktioner skotningFWC2007.xls
Tidsfunktioner skördare FWC 2007.xls
Productivity and sorting Nordic test chain final felling NPC. Calc
Productivity and sorting Nordic test chain NPC thinning medium TB. Calc

1 Indata for timber transport with road vehicle		
Gasoline price		1,092
Gasoline consumption in average (l/100km)		53,500
Fuel = (2) / 100 x (1)		0,584
Tires		0,069
Maintenance		0,084
Toll		
TOTAL €/KM = (3) + (4) + (5) + (6)		0,738
TOTAL €/KM = (3) + (4) + (5)		0,738
Truck cost		192,993
Semi trailer cost		54,435
Crane cost		
Insurance		29,732
Taxes (incl. axle tax)		20,750
Daily vehicle cost (€/jour) = (9)+(10)+(11)+(12)+(13)		297,910
Wages and other compensations		327,076
Labour charges		145,983
Other fees: hotel, restaurant…		
Daily crew cost (€/jour) = (14)+(15)+(16)		473,059
Daily structural (overheads)costs (€/jour)		0,000
TOTAL €/JOUR = (14)+(18)+(19)		770,968
Hours per day		18:69

Load capacity (normal regulation vs. usual practices?)		44,55
Load capacity (specific wood regulation if any)		
Loading (hh:mm)		00:45
Unloading (hh:mm)		00:29
Empty backhaulage (km or %)		48

Tab 6 Performance of road transport of sawlogs. Truck 3 axles + trailer 4 axles with removable crane. Single FWC Scandinavian Pine chain

2.1.4 Assumptions

The harvested volume is described as solid cubic metres under bark of reasons that the national statistics are referred to this assortment (Table 7). However the bark is vital part of the product since it yields energy for production processes and also contains carbon that is to be recorded in the chain. The amount of bark on the trees varies with their age and size, also with its actual position on the stem. In this case for the reason of simplicity it is assumed that all logs in the same cutting mode have the same percentage of bark.

2.1.5 Conversion factors

	Product ID	**Log length m**	**Top diam. Mm ob**	**Bark content, %**	**Fresh weight ton per m^3ob**	**Carbon, tons per m^3sub**
Saw timber final felling	2042000	4,70	220	11,8	0,937	0,240
Saw timber thinning	2042000	4,65	180	14,2	0,937	0,246
Pulp wood final felling	2043000	4,17	146	11,8	0,937	0,240
Pulp wood thinning		4,20	129	14,2	0,937	0,246
Fuel wood final felling(downgraded industrial wood)	2044000	4,47	189	11,8	0,937	0,240
Fuel wood thinning (downgraded industrial wood)	2044000	4,40	139	14,2	0,937	0,246

Tab 7 Raw material properties in Single FWC Scandinavian Pine chain based on general averages

Product	Product ID	Log length [m]	Top diam. [mm ob}	Bark content, [%]	Fresh weight [ton per m³ob] 1)	a. Carbon, [tons per m³sub]	b. Carbon, in bark [tons per m³sub]	a+b
Saw timber final felling	2042000	4,5	220	11,6	0,826	0,205	0,017	0,222
Saw timber thinning	2042000	4,4	186	12,8	0,876	0,196	0,019	0,215
Pulp wood final felling	2043000	4,2	146	10,9	0,866	0,195	0,017	0,212
Pulp wood thinning		4,2	129	13,1	0,899	0,189	0,021	0,210
Fuel wood final felling(downgraded industrial wood)	2044000	4,3	189	11,2	0,756	0,2	0,017	0,217
Fuel wood thinning (downgraded industrial wood)	2044000	4,4	139	13,0	0,765	0,19	0,02	0,210

1) Fuel wood calculated as 90% of the fresh weight of the initial fresh weights of the industrial

Tab 8. Raw material properties in Single FWC Scandinavian Pine chain, based on bucking simulation and predictions of bark of tree data from selected plots in the county of Västerbotten

2.1.6 Data delivered to M1

Indicator	Ind. unit	Clear cut with large single-grip harvester	Final measuring and sorting of pine logs according to quality at sawmill	Pre-commercial thinning of planted pine stand in young phase	Felling with large harvester	Forwarding of pine after:	
						thinning	final felling
Process ID		1000003	1000025	1000027	1000034	1000046	1000058
LI02c - Production cost - labour costs	EUR	1,14	0,29	191,7	2,38	1,64	1,51
LI02d - Production cost - energy costs	EUR	0,81	0	18,3	1,67	1,12	1,04
LI02e - Other productive costs	EUR	0,04	0	0	0,18	0,12	0,06
LI02f - Non-productive costs	EUR	1,88	0	6,7	3,89	1,46	1,36
LI09a - Employment	person	0,05066	0,0138	14,7	0,067	0,072654	0,067

male							
LI09b - Employment female	person	0,00495	0,001364	1,63	0,007	0,007103	0,00655
LI09c - Employment urban	person	0,04531	0,012427	13,39	0,094	0,064998	0,05993
LI09d - Employment rural	person	0,01029	0,002728	2,93	0,021	0,014759	0,01361
LI10a - Wages and salaries male	EUR	1,14	0,29	191,7	2,38	1,64	1,51
LI10b - Wages and salaries female	EUR	1,14	0,29	191,7	2,38	1,64	1,51
LI13.2.a - Energy use (renewable)	KWh	0	0	0	0	0	0
LI13.2.b - Energy use (non-renewable)	KWh	26,5	0	487	54	38,3	36
LI14.2.e - Carbon sequestration in harvested wood products	tons of C	0,24	0	0,806	0,24	0,24	0,24
LI14.1 - Greenhouse gas emissions per process	tons of CO2 eq.	2,51	0	49,1	5,12	3,63	3,44
LI11.1.a - Occupational accidents (non-fatal) - absolute numbers	cases	2,5E-07		8	2,5E-07	2,5E-07	2,5E-07
LI11.1.b - Occupational accidents (non-fatal) - % per 1000 employees		0,004		0,006	0,004	0,004	0,004
LI11.1.c - Occupational accidents (fatal) - absolute numbers	cases	2,5E-08		0,652	2,5E-08	2,5E-08	2,5E-08
LI11.1.d - Occupational accidents (fatal) - % per 1000 employees		0,07		0,07	0,07	0,07	0,07
LI11.2.b - Occupational diseases - % per 1000 employees	%	0,3		0,3	0,3	0,3	0,3
LI19.3.a - Non-greenhouse gas emissions into air - SO2	kg	2,14	0	78,1	4,37	3,1	2,91
LI19.3.b - Non-greenhouse gas emissions into air - Nox	kg	32,3	0	62,6	65,7	45,9	43,1
LI19.3.c - Non-greenhouse gas emissions into air - NMVOC	kg	5,61	0	1,67	11,4	8,11	7,62

LI19.3 - Non-greenhouse gas emissions into air - NH3		1,71E-06	0	0,000054	3,49E-06	2,48E-06	2,33E-06
LI24.1.b - Persons employed - high skilled workers	cases	0,0556	0,015154	16,32	0,116	0,079	0,074

Indicator	**Ind. unit**	**Transport by 60t truck with crane acc to assortment**				**Final measuring and sorting acc. to quality at pulpmill**	**Final measuring and sorting acc. to quality at:**	
							sawmill	**pulpmill**
Process ID		1000101	1000102	1000103	1000104	1000109	1000116	1000118
LI02c - Production cost - labour costs	EUR	0,024505	0,024505	0,024505	0,024505	0,29	0,29	0,29
LI02d - Production cost - energy costs	EUR	0,029194	0,029194	0,029194	0,029194	0	0	0
LI02e - Other productive costs	EUR	1,08	1,08	1,08	1,08	0	0	0
LI02f - Non-productive costs	EUR	0,023087	0,023087	0,023087	0,023087	0	0	0
LI09a - Employment male	person	0,004225	0,004225	0,004225	0,004225	0,0138	0,0138	0,0138
LI09b - Employment female	person	0,000375	0,000375	0,000375	0,000375	0,001364	0,001364	0,001364
LI09c - Employment urban	person	0,003772	0,003772	0,003772	0,003772	0,012427	0,012427	0,012427
LI09d - Employment rural	person	0,00083	0,00083	0,00083	0,00083	0,002728	0,002728	0,002728
LI10a - Wages and salaries male	EUR	0,052	0,052	0,052	0,052	0,29	0,29	0,29
LI10b - Wages and salaries female	EUR	0,052	0,052	0,052	0,052	0,29	0,29	0,29
LI13.2.a - Energy use (renewable)	KWh	0	0	0	0	0	0	0
LI13.2.b - Energy use (non-renewable)	KWh	1,075	1,075	1,075	1,075	0	0	0
LI14.2.e - Carbon sequestration in harvested wood products	tons of C	0,24	0,24	0,24	0,24	0,24	0,24	0,24
LI14.1 - Greenhouse gas emissions per process	tons of CO2 eq.	0,0982	0,0982	0,0982	0,0982	0	0	0
LI15.1.a - Transport distance - road transport		93	93	93	93			
LI15.2.a - Freight volume - road transport		4102523	2970792	575554,7	2040603			
LI19.3.a - Non-greenhouse gas emissions into air - SO2	kg	0,0822	0,0822	0,0822	0,0822	0	0	0
LI19.3.b - Non-greenhouse gas emissions into air - Nox	kg	0,761	0,761	0,761	0,761	0	0	0
LI19.3.c - Non-	kg	0,218	0,218	0,218	0,218	0	0	0

greenhouse gas emissions into air - NMVOC								
LI19.3 - Non-greenhouse gas emissions into air - NH3		0,000226	0,000226	0,000226	0,000226	0	0	0
LI24.1.b - Persons employed - high skilled workers	cases	0,080843	0,080843	0,080843	0,080843	0,015154	0,015154	0,015154

2.2 Spruce test chain

2.2.1 Set-up of test chain

The spruce chain, located in Baden Wurttemberg, Germany, was designed to be the first chain at which MCA and CBA should be tested and for this reason two strands of alternatives (=chains) were modelled for M2 and M3. Nevertheless, similarly to the pine chain, certain aspects of the chain were chosen to be left out at this point of time for reasons of simplicity. Those were:

- Trees to be removed in pre-commercial thinning
- Harvest residues from thinning operations
- 1.-2. thinning operation: only harvesting and forwarding costs were considered which add to the value of the chosen operation from thinning 3-6.
- Pulpwood from harvesting processes has not been followed along its way to the mill

The two followed chains were chain a:
Starting from a spruce forest stand with natural regeneration at a steep slope (> 45 % inclination), with 6 thinnings and motor-manual selective harvesting of long whole trees (97%) and harvest residues (3%) left in forest, involving haulage by skidder, cross-cutting into long sawlogs (92%) and pulpwood (8%). Calculations in this case are only for one assortment (sawlogs). Transport by 40 t truck to millgate.
As well as chain b:
Planted spruce forest stand in easy terrain (< 44% inclination), involving a lower number of stems (target: 200 future trees) and 6 thinnings, fully mechanised selective harvesting by medium harvester at targeted DBH of 35 cm with 20 m distance between skidding lines. Assortments: 69 % saw logs and 31 % pulpwood, harvest residues of 5 % from the harvested trees (95 %) were left in forest. Calculations in this case are only for one assortment (sawlogs). Forwarding by forwarder, transport by 40 t truck to millgate.

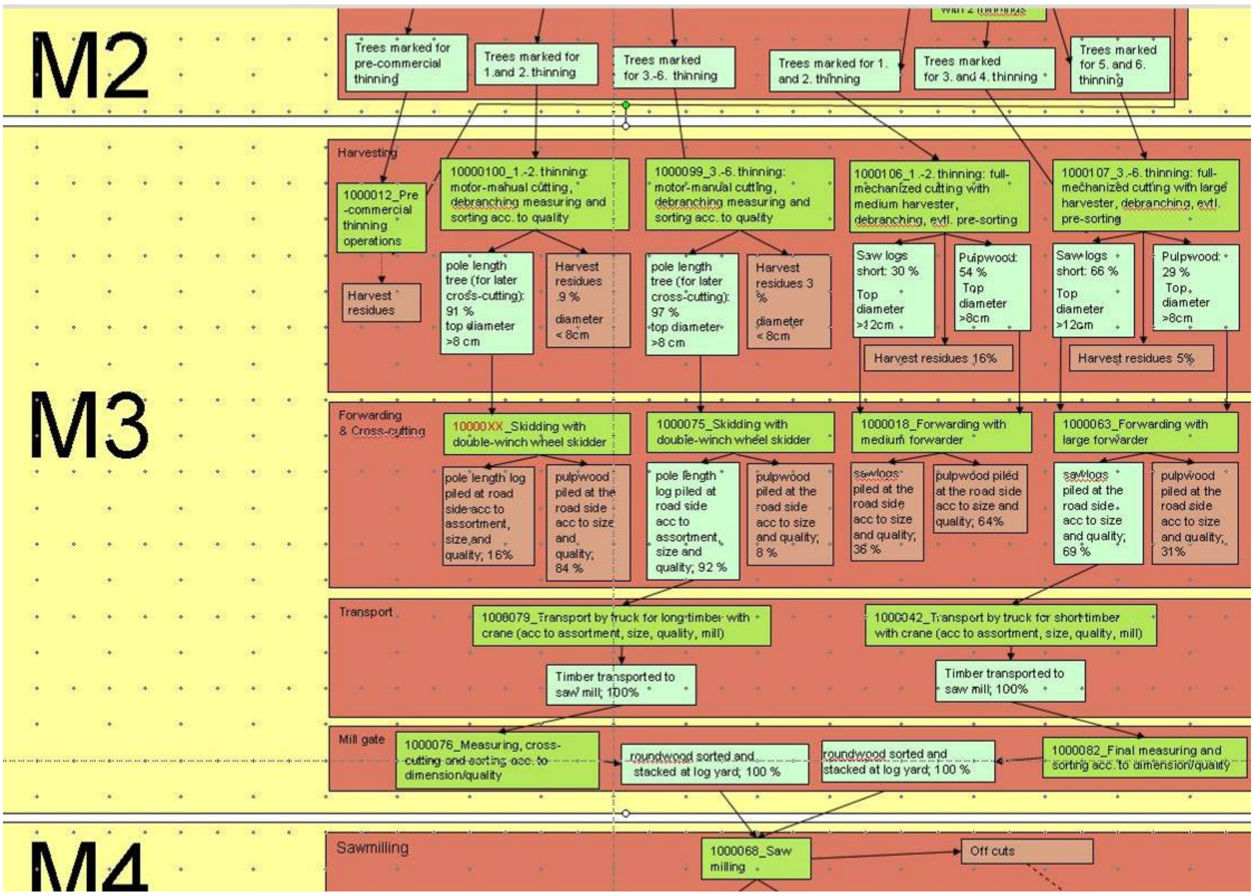


Fig 2: M3 part of the Pine test chain with input from M2 and output to M4.

Input Data from M2 in chain A:

Thinning id) and phase of development	**h_o (m)**	**N/ha**	**dbh (cm)**	**v (m^3 o. bark)** *(Vfm_D m.R.)*	**V/ha (m^3 o. bark)** *(Vfm_D m.R.)*
1) medium	12.5	652	14	-	56
2) medium	15.5	268	19	-	53
3) medium	18	136	24	-	50
4) medium	21	87	28	-	50
5) medium	23.5	62	33	-	53
6) medium	26	50	37	-	50

Input Data from M2 in chain B:

Thinning id) and phase of development	**h_o (m)**	**N/ha**	**dbh (cm)**	**v (m^3 o. bark) (Vfm_D m.R.)**	**V/ha (m^3 o. bark) (Vfm_D m.R.)**
1) medium	15	420	12	0.07	30
2) medium	18	730	15	0.13	95
3) medium	21	520	16	0.19	100
4) medium	24	250	18	0.26	65
5) adult	27	130	20	0.36	45
6) adult	30	50	20	0.39	20

2.2.2 Calculation Models:

The production output of the harvesting process, the assortments, were calculated with HOLZERNTE 7.0 which is the calculation model for wood harvesting and marketing developed by FVA. The calculation of harvesting and forwarding costs were also calculated with HOLZERNTE 7.0. The machine costs, harvesting, forwarding, transportation and millgate operations were calculated with an excel based calculation models from FVA and ALUFR, based on the figures given in paragraph 2.2.3 "Calculation modes".

2.2.3 Calculation modes

Machine costs were calculated with an excel based calculation model from FVA, based on the following figures:

Investment	€	
Depreciation	years	1 year for motormanual equipment, 4 years for harvester, 7 years for forwarders and skidders
Interest rate	%	4% based on Euro market 6 months bonds 2001 - 2006 + 1,9 %
End value	€	
Administrative costs	€	allocated per PMH
Social costs and taxes		for labour
Taxes machine		
Machine Hours	PMH	productive machine hours, PMH (related to work period according to each cost model
Moving costs		allocated per PMH
Labour cost	€/PMH	excluding taxes and social costs
Infrastructure costs	€/ m³	costs for infrastructure roads and terminals allocated per m³
Fuel use	kg/PMH	
Use of lubricants	kg/PMH	
Use of chemicals	kg/PMH	
Fuel cost	€/kg	incl. taxes
Lubrication cost	€/kg	incl. taxes
Cost for chemicals	€/kg	incl. taxes
Cost for maintenance	€/PMH	includes repair, tyres

For the calculations of harvesting operations in addition to machine costs an excel based calculation from ALUFR was used including the following parameters:

LI 10 Employment		Data source
Annual cutting volume of sawlogs and pulpwood (spruce, fir, douglasfir), m³/y	1676067	Statistisches Jahrbuch der Forstverwaltung BW, 2004
Timber cut per assortment, m³/y	1237775	= Annual cutting volume of sawlogs and pulpwood * Share of harvesting mode
Share of motormanual harvesting, %	74	Expert knowledge, FVA
Share of fully mechanised harvesting, %	26	Expert knowledge, FVA
Working days / year	220	Expert knowledge, FVA
Working hours / shift	8	Expert knowledge, FVA
No. Shifts/day	1	Expert knowledge, FVA

Working hours/year	1760	= number of shifts * daily working hours *annual working days
Employees, persons	1334	Statistisches Jahrbuch der Forstverwaltung BW, 2005
Male employees, persons	1321	Statistisches Jahrbuch der Forstverwaltung BW, 2005
Female employees, persons	13	Statistisches Jahrbuch der Forstverwaltung BW, 2005
Male employees, %	99,0	=Total employees /100 * Male employees
Female employees, %	1,0	=Total employees /100 * Female employees
Employment, persons / m³		= 1/Productivity
Productivity in mechanized harvesting at 20 cm DBH, m³/h	12,7	Holzernte
Productivity in mechanized harvesting at 35 cm DBH, m³/h	15,3	Holzernte
Productivity in motormanual harvesting, m³/h	2,5	Expert knowledge, FVA

LI 11 wages and salaries		**Source**
For motormanual harvesting:		
wage difference in trades for men, %	100	IAB 04/2005; "Lohnunterschiede zwischen Frauen und Männern
wage difference in trades for women, %	80,2	IAB 04/2005; "Lohnunterschiede zwischen Frauen und Männern
For machine operations:		
wage difference in machine operations for men, %	100	IAB 04/2005; "Lohnunterschiede zwischen Frauen und Männern
wage difference in machine operations for men, %	79,2	IAB 04/2005; "Lohnunterschiede zwischen Frauen und Männern

LI 12 Occupational accidents		Data source
fatal accidents in motormanual harvesting, number	7	Unfallstatistik im öffentlichen Dienst, BW, 2003
non-fatal accidents in motormanual harvesting, number	4000	Unfallstatistik im öffentlichen Dienst, BW, 2004
Occupational accidents per m³ ub, n/ m³ub		= number of accidents / annual cutting volume of sawlogs and pulpwood

LI 13 Education time		Data source
Annual education time per employee, working days	1	expert knowledge (fobawi)
Working hours / shift	8	
Education time, h/m³ ub		= lost productive working hours / process-based annual cutting volume of sawlogs and pulpwood
costs for education, €/m³ ub		= (lost productive working hours * wages, €/h acc to gender ratio (see Indicator 11)) / process-based annual cutting volume of sawlogs and pulpwood

For the calculations of forwarding operations in addition to machine costs an excel based calculation from ALUFR was used including the following parameters:

LI 10 Employment		Data source
Annual cutting volume of sawlogs and pulpwood (spruce, fir, douglasfir), m³/y	1676067	Statistisches Jahrbuch der Forstverwaltung BW, 2004
Timber cut per assortment, m³/y	1014170	= Annual cutting volume of sawlogs and pulpwood * Share of harvesting mode
Share of motormanual harvesting, %	74	= skidding of long logs; Expert knowledge, FVA
Share of fully mechanised harvesting, %	26	= forwarding of short logs; Expert knowledge, FVA
Working days / year	220	Expert knowledge, FVA
Working hours / shift	8	Expert knowledge, FVA
No. Shifts/day	1	Expert knowledge, FVA
Working hours/year	1760	= number of shifts * daily working hours *annual working days
Employees, persons	1334	Statistisches Jahrbuch der Forstverwaltung BW, 2005
Male employees, persons	1321	Statistisches Jahrbuch der Forstverwaltung BW, 2005
Female employees, persons	13	Statistisches Jahrbuch der Forstverwaltung BW, 2005
Male employees, %	99,0	=Total employees /100 * Male employees
Female employees, %	1,0	=Total employees /100 * Female employees
Employment, persons / m³		= 1/Productivity
Productivity in skidding of long logs from felling with 20 cm DBH, m³/h	5,55	Holzernte
Productivity in skidding of long logs from felling with 35 cm DBH, m³/h	9,66	Holzernte
Productivity in forwarding of short logs from felling with 20 cm DBH, m³/h	12,5	Holzernte
Productivity in forwarding of short logs from felling with 35 cm DBH, m³/h	13,5	Holzernte
Productivity in motormanual harvesting, m³/h	2,5	Expert knowledge, FVA

LI 11 wages and salaries		**Source**
For motormanual harvesting:		
wage difference in trades for men, %	100	IAB 04/2005; "Lohnunterschiede zwischen Frauen und Männern
wage difference in trades for women, %	80,2	IAB 04/2005; "Lohnunterschiede zwischen Frauen und Männern
For machine operations:		
wage difference in machine operations for men, %	100	IAB 04/2005; "Lohnunterschiede zwischen Frauen und Männern

wage difference in machine operations for men, %	79,2	IAB 04/2005; "Lohnunterschiede zwischen Frauen und Männern

LI 12 Occupational accidents		Data source
fatal accidents in motormanual harvesting, number	7	Unfallstatistik im öffentlichen Dienst, BW, 2003
non-fatal accidents in motormanual harvesting, number	4000	Unfallstatistik im öffentlichen Dienst, BW, 2004
share of activity in number of accidents, mm harvesting, %	67	kwf, 2005
share of activity in number of accidents, forwarding, %	3	kwf, 2005
Occupational accidents per m³ ub, n/ m³ub		= number of accidents * share of activity's accidents / annual cutting volume of sawlogs and pulpwood

LI 13 Education time		Data source
Annual education time per employee, working days	1	expert knowledge (fobawi)
Working hours / shift	8	
Education time, h/m³ ub		= lost productive working hours / process-based annual cutting volume of sawlogs and pulpwood
costs for education, €/m³ ub		= (lost productive working hours * wages, €/h acc to gender ratio (see Indicator 11)) / process-based annual cutting volume of sawlogs and pulpwood

For the calculations of transport operations an excel based calculation from ALUFR was used including the following parameters, as well as machine costs:

LI 10 Employment		Data source
Annual cutting volume of sawlogs and pulpwood (spruce, fir, douglasfir), m³/y	1676067	Statistisches Jahrbuch der Forstverwaltung BW, 2004
Timber cut per assortment, m³/y	1014170	= Annual cutting volume of sawlogs and pulpwood * Share of harvesting mode
Share of motormanual harvesting, %	74	= skidding of long logs; Expert knowledge, FVA
Share of fully mechanised harvesting, %	26	= forwarding of short logs; Expert knowledge, FVA
Working days / year	220	Expert knowledge, FVA
Working hours / shift	8	Expert knowledge, FVA
No. Shifts/day	1	Expert knowledge, FVA
Working hours/year	1760	= number of shifts * daily working hours *annual working days
Employees, persons	1334	Statistisches Jahrbuch der Forstverwaltung BW, 2005
Male employees, persons	1321	Statistisches Jahrbuch der Forstverwaltung BW, 2005

Female employees, persons	13	Statistisches Jahrbuch der Forstverwaltung BW, 2005
Male employees, %	99,0	=Total employees /100 * Male employees
Female employees, %	1,0	=Total employees /100 * Female employees
Employment, persons / m³		= 1/Productivity
Loading time per load, min/load	50	expert knowledge (fobawi)
Unloading time per load, min/load	30	expert knowledge (fobawi)
Distance (loaded plus unloaded), km	120	expert knowledge (fobawi)
Backhaulage, %	0	expert knowledge (fobawi)
Time per load, h	3,33	= (loading time + unloading time + transport time)/60 min
weight of fresh spruce per m³, t	0,88	expert knowledge, Skogforsk
Load volume, m³ u.b.	20,592	= transport load, t * weight of fresh wood per m³, t
Productivity, m³/h	2,5	= load volume / time per load

LI 11 wages and salaries		**Source**
For motormanual harvesting:		
wage difference in trades for men, %	100	IAB 04/2005; "Lohnunterschiede zwischen Frauen und Männern
wage difference in trades for women, %	80,2	IAB 04/2005; "Lohnunterschiede zwischen Frauen und Männern
For machine operations:		
wage difference in machine operations for men, %	100	IAB 04/2005; "Lohnunterschiede zwischen Frauen und Männern
wage difference in machine operations for men, %	79,2	IAB 04/2005; "Lohnunterschiede zwischen Frauen und Männern

LI 13 Education time		Data source
Annual education time per employee, working days	1	expert knowledge (fobawi)
Working hours / shift	8	
Education time, h/m³ ub		= lost productive working hours / process-based annual cutting volume of sawlogs and pulpwood
costs for education, €/m³ ub		= (lost productive working hours * wages, €/h acc to gender ratio (see Indicator 11)) / process-based annual cutting volume of sawlogs and pulpwood

LI 17 Distance and Load		Data source
Transport distance road transport, km	60	expert knowledge (fobawi)
Transport load long sawlogs, t	23,4	expert knowledge (fobawi)
Transport load short sawlogs, t	23,5	expert knowledge (fobawi)

	PARAMETERS DETERMINING COUTRY/LOCAL CONDITIONS	Tractor + semi-trailer 5 axles with crane	Solid bulk 5 axles	Tractor + long-load dolly 5 axles with crane
1	Gasoil price	0,860	0,860	0,860
2	Gasoil consumption in average (l/100km)	45,000	45,000	45,000
3	Fuel = (2) / 100 x (1)	0,387	0,387	0,387
4	Tires	0,030	0,030	0,030
5	Maintenance	0,090	0,090	0,090
6	Toll	0,062	0,031	0,062
7	TOTAL €/KM = (3) + (4) + (5) + (6)	0,569	0,538	0,569
8	TOTAL €/KM = (3) + (4) + (5)	0,507	0,507	0,507
9	Tractor cost	50,000	44,872	50,000
10	(Semi) trailer cost	11,538	19,231	11,538
11	Crane cost	included in (9)	included in (9)	included in (9)
12	Insurance	included in (13)	18,682	included in (13)
13	Taxes (incl. axle tax)	2,888	5,712	2,888
14	Daily vehicle cost (€/jour) = (9)+(10)+(11)+(12)+(13)	64,427	88,496	64,427
15	Wages and other compensations	166,866	166,866	166,866
16	Labour charges	186,890	148,988	186,890
17	Other fees: hotel, restaurant…			
18	Daily crew cost (€/jour) = (15)+(16)+(17)	353,757	315,854	353,757
19	Daily structural (overheads) costs (€/jour)	84,615	84,615	84,615
20	TOTAL €/JOUR = (14)+(18)+(19)	502,799	488,966	502,799
21	Hours per day	10:00	10:00:00	10:00
22	Load capacity (normal regulation vs. usual practices?)	23,5	18,9	23,4
23	Load capacity (specific wood regulation if any)			
a1	Loading (hh:mm)	00:50	03:28	00:50
a2	Unloading (hh:mm)	00:30	00:20	00:40
a3	Empty backhaulage (km or %)	42%		48%

For the millgate operations an excel based calculation from FVA was used including the following parameters:

Annual Production Capacity	m3/year
Investment log yard	€
Depreciation	10 years
End value	10 %
Operating costs	3% of investment
Interest rate	5,5%
Working days	days / year

Working hours	hours / shift
No. Shifts	Shifts /day
Working hours	hours/year
Staff costs	Euro/year
No. of staff	staff per shift
Installed machine power	kW
utilization factor	
Power usage lights, heat etc	kW
energy price	€/kWh
No. of log stackers	

2.2.4 Assumptions:

- Top diameter of the logs: 12 cm
- Top diameter of pulpwood: 8 cm

2.2.5 Conversion Factors:

1m³ ub=1.1m³ ob=1.1*0.18856 t C=0,2074 t C

2.2.6 Data delivered to M1

Chain A (natural regeneration):

		Harvesting		Forwarding		Transport	Mill Gate
Indicator	**Unit**	**1.-2. thinning**	**3.-6. thinning**	**1.-2. thinning**	**3.-6. thinning**		
Process ID		1000100	1000099	1000108	1000075	1000079	1000076
LI 2a Production cost of process inputs from the FWC	€/m³ ub	30,10	13,68	8,25	6,91	10,4	3,17
LI02c - Production cost - labour costs	EUR	25,64	11,66	6,91	8,17		
LI02d - Production cost - energy costs	EUR	1,35	0,61	0,71	0,84		
LI 9a Employment male	persons/m³ub	0,000225	0,000225	0,0001	0,0000582	0,0000557	0,00002
LI 9b Employment female	persons/m³ub	0,000002	0,000002	0,000001	0,0000006	0,0000005	not available
LI 9c Employment rural	persons/m³ub	0,000227	0,000227	0,0001	0,0000588	0,0000562	0,00002

LI 9d Employment urban	persons/m³ub	0	0	0	0	0	0
LI 10a Wages and salaries male	€/m³ ub	15,84	7,20	1,35	1,13	13,5	0,58
LI 10b Wages and salaries female	€/m³ ub	15,84	7,20	1,35	1,13	10,69	0,58
LI 11.1.a Occupational accidents (non-fatal):	cases/ m³ub	0,0032	0,0032	0,0001	0,000183	not available	not available
LI 11.1.c Occupational accidents (fatal)	cases/ m³ub	0,000006	0,000006	0,0000002	0,0000002	not available	not available
LI 12.1 Education time per person-year working time in the process	h FTE /p/m³ub	0,000006	0,000006	0,000008	0,000008	not available	not available
LI12.2 - Training expenditure per person-year working time in the process	€/ h FTE /p/m³ub	0,000229	0,000229	0,000106	0,000106	not available	not available
LI 13.2.b Energy use (non-renewable)	KWh/m³ ub	11,6	5,30	8,41	7,04	13,4096	6,45
LI 15.1.a Transport distance road transport	km/ m³ ub	0	0	0	0	60	0
LI 15.2.a Freight volume road transport	t km/ m³ ub	0	00	0	0	23,4	0
LI 14.2.e Carbon sequestration in harvested wood products:	t C/ m³ob	0,2074	0,2074	0,2074	0,2074	0,2074	0,2074
LI 14.1 1 Greenhouse	t CO_2 Equivalents/	0,00318	0,00144	0,00227	0,00190	0,00376	0,0046

gas emissions per process	m^2ub						
LI19.3.a - Non-greenhouse gas emissions into air - SO2	kg	0,00008	0,00004	0,00156	0,00132	0	0
LI19.3.b - Non-greenhouse gas emissions into air - Nox	kg	0,00301	0,00137	0,02906	0,02456	0	0
LI19.3.c - Non-greenhouse gas emissions into air - NMVOC	kg	0,1384	0,06291	0,00009	0,00008	0	0
LI22.1 - Generation of waste	kg	0,01006	0,0047		0,0413	0	0
LI22.2 - Hazardous waste	kg	0,0011	0,0005		0,0194	0	0

Chain B (planted):

		Harvesting		Forwarding		Transport	Mill Gate
Process ID		1000106	1000107	1000018	1000063	1000042	1000082
Indicator	Unit	1.-2. thinning	3.-6. thinning	1.-2. thinning	3.-6. thinning		
LI 2a Production cost – raw materials from the FWC	€/m³ ub		7,5			9,3	3,59
LI02c - Production cost - labour costs	€/m³ ub	19,08	15,32	8,07	6,54		
LI02d - Production cost - energy costs	EUR	2,06	1,61	1,15	0,93		
LI05.1.a - Enterprises and forest holdings - micro and small enterprises (0-49 employees)	cases	0,000148	0,000148	0,000148	0,000148		

LI 9a Employment male	persons/m³	0,000043	0,0000368	0,0000450	0,0000318	0,0000727	0,00001
LI 9b Employment female	persons/m³	0,0000004	0,0000004	0,0000004	0,0000003	0,0000007	not available
LI 9c Employment urban	persons/m³	0	0	0	0	0	0
LI 9d Employment rural	persons/m³	0,000047	0,0000371	0,0000455	0,0000322	0,0000735	0,00001
LI 10a Wages and salaries male	€/m³ ub	O,96	0,78	1,49	1,21	13,5	0,49
LI 10b Wages and salaries female	€/m³ ub	O,96	0,78	1,49	1,21	10,69	0,49
LI 11.1.a Occupational accidents (non-fatal):	cases/ m³ub	not available	not available	0,00019	0,00019	not available	not available
LI11.1.c - Occupational accidents (fatal) - absolute numbers	Cases/ m³ub	not available	not available	3E-07	3E-07	not available	not available
LI 12.1 Education time per person-year working time in the process	h FTE /p/m³ub	0,000018	0,000018	0,000012	0,000012	0,000012	not available
LI12.2 - Training expenditure per person-year working time in the process	€/ h FTE /p/m³ub	0,000279	0,00158	0,000167	0,000167	0,000167	not available
LI 13.2.b Energy use (non-renewable)	KWh/m³ ub	8,6	8,58	11,32	9,17	10,74	2,32
LI 14.2.e Carbon sequestration in harvested wood products:	t C/ m³ob	0,2074	0,2074	0,2074	0,2074	0,2074	0,2074
LI 14.1 Greenhouse gas emissions per process	t CO_2 equivalents /m3 ub	0,00232	0,00231	0,00305	0,00247	0,0030	0,0016
LI 15.1.a	Km/m³ ub					60	

Transport distance road transport							
LI 15.2.a Freight volume road transport	t					23,5	
LI19.2.c - Water pollution with hazardous substances	m3		0,00297				
LI19.3.a - Non-greenhouse gas emissions into air - SO2	kg	0,00381	0,05534	1,06E-05	0,00172		
LI19.3.b - Non-greenhouse gas emissions into air - Nox	kg	0,07099	0,00018	0,039	0,032		
LI19.3.c - Non-greenhouse gas emissions into air - NMVOC	kg	0,00023		0,000125	0,0001		
LI19.3 - Non-greenhouse gas emissions into air - NH3			0,05499				
LI22.1 - Generation of waste	kg	0,08683	0,04564	0,0387	0,0313	0	0
LI22.2 - Hazardous waste	kg	0,07207		0,0271	0,0219	0	0

2.3 Eucalypt test chain

The main focus of the Iberian test chain is on pulp production within the Iberian peninsula. For this pulp production wood from coniferous and deciduous trees is needed. For this reason it consists at M3 level out of two separate parts: harvesting, forwarding and transport of Eucalypt from plantations on the Iberian Peninsula (dark red background in Fig 4), as well as of imported pine wood from Scandinavia (light red background in Fig 4). For the later only the transport is described, as the harvesting, etc. procedure is that of pulpwood in the pine test chain and consequently described there.

The M3-processes of Eucalyptus harvesting to transport to mill are described in the following.

Also for the Eucalypt chain some aspects were included for respecting reality.

Those were: Trees to be removed in pre-commercial thinning in second and third rotation coppice
Followed were, however,

- Planted Eucalyptus ready for first rotation harvesting

- Eucalyptus from coppice ready for first and second rotation harvesting (with precommercial thinning)

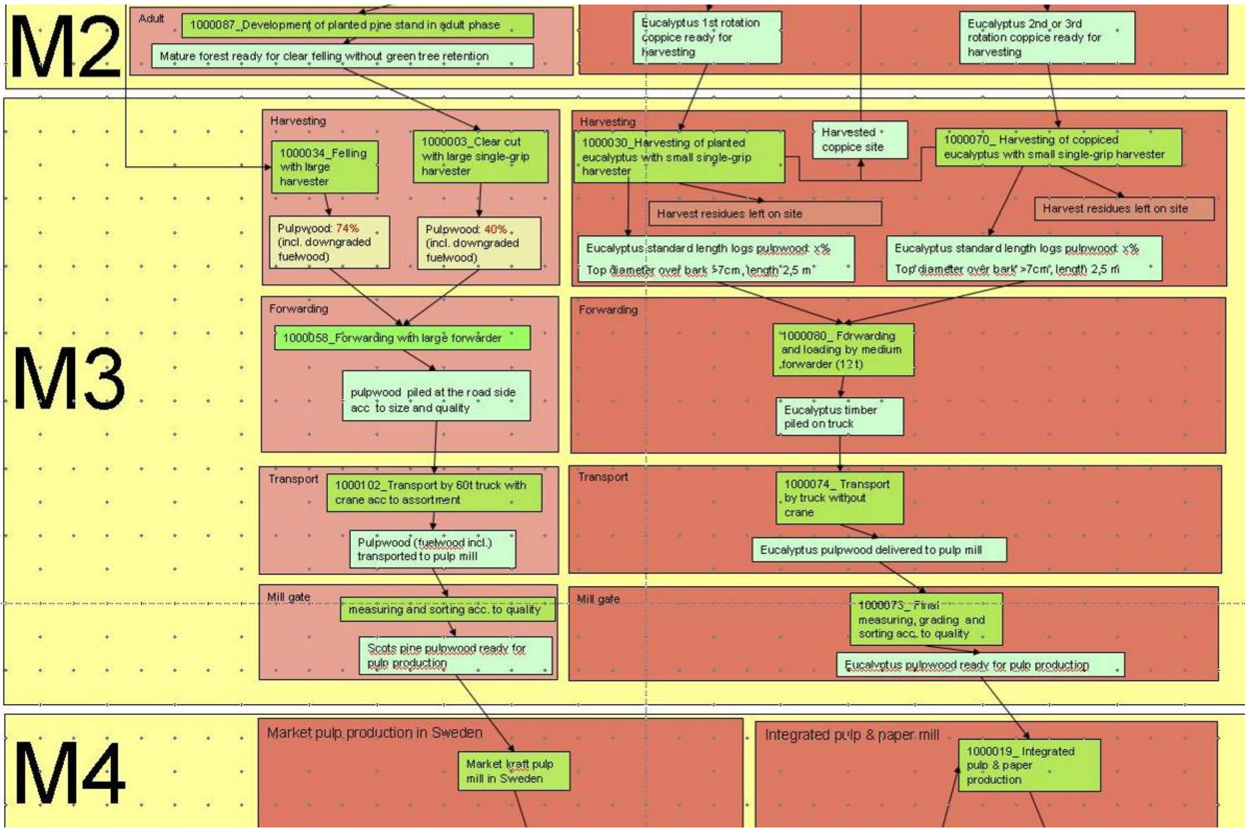


Fig 3: M3 part of the Pine test chain with input from M2 and output to M4.

2.3.2. Models for calculation, (which models were used, e.g. Sima Pro, Holzernte, …)

The cost model used is the Procou Model, developed by AFOCEL in the 90's.

It allows to get a production cost.

2.3.3. Calculation modes

Hypothesis in Portuguese conditions for employment calculation

Productivity per year	woodcutters	2000	m^3 ub/y
	harvester	16000	m^3 ub/y
	medium forwarder	18000	m^3 ub/y

Share of male and female operators	men 99%	women 1%
Eucalyptus annual cutting volume	2683000	m3fub
Eucalyptus mechanization rate	60	%

	Harvested volume (m³ ub)	Total number of persons	Number of men	Number of women	Men harvested volume (m³ ub/y)	Women harvested volume (m³ ub/y)
woodcutters	1073200	537	531	5	1062468	10732
harvester	1609800	101	100	1	1593702	16098
Forwarder	2683000	149	148	1	2656170	26830

Hypothesis for the calculation of total greenhouse gas emission per process.

The total greenhouse gas emission (C) can be share in two parts (C = A+B):

Gas emission to make the machine (A)

Gas emission from oil burning during the process (B)

$$A = \frac{(\text{weight of the machine} \times \text{machine building C coef.} \times \text{C to CO2 coef.})}{(\text{lifetime of the machine} \times \text{annual harvested volume})}$$

$$B = \frac{(\text{oil consumption per hour} \times \text{number of hour per year} \times \text{oil burning C coef.} \times \text{C to CO2 coef.})}{\text{annual harvested volume}}$$

	Motormanual	harvester	forwarder
Weight of the machine (t)	0.023	20	9.5
Machine building C coefficient	1.5 [2]	1.5 [2]	1.5 [2]
C to CO2 coefficient	3.67	3.67	3.67
Lifetime of the machine (year)	1	7	10
Annual harvested volume (m3 ub)	2000	16000	18000
Oil consumption per hour (L)	1.1 [4]	12.25 [3]	11 [3]
Number of hour per year	1000	1700	1782
Oil burning C coefficient	0.73/1000 [1]	0.73/1000 [1]	0.73/1000 [1]
A (t of C/ m3 ub)	6.3308E-05	0.000983	0.0002905
B (t of C/ m3 ub)	0.00147351	0.003487	0.0029175
C (t of C/ m3 ub)	0.00153681	0.0044701	0.0032081

[1] : ADEME 2005, page 16, tableau 2, Diesel (divided by 1000 to convert coefficient in ton)

[2] : ADEME 2005, page 149, 1st paragraph

[3] : KVLAC 2003, page 179, Table 1, Ireland, Class II for harvester and forwarder

[4] : Harvested sample site

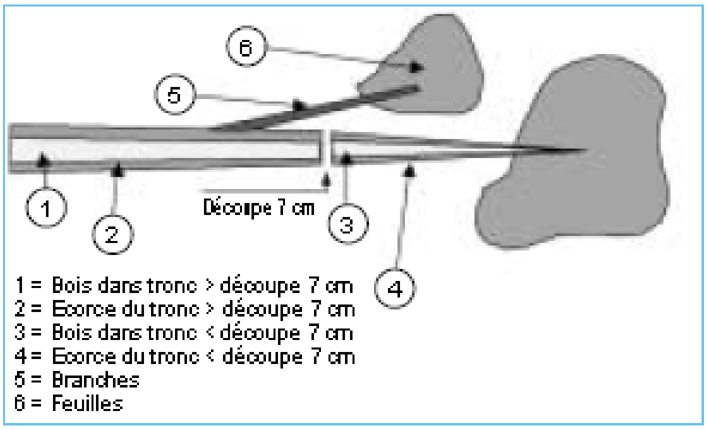
2.3.4. Assumptions

The product share is the same between planted eucalypts and coppice eucalypts after harvesting.

He is divided in two parts: pulpwood logs and harvest residues.

The pulpwood logs represent 77 % and the harvest residues (bark, leaves, branches, stem < 7cm) 23 %. We assume that barking is all done on the field.

This share is made only for the above ground biomass as shown on the picture below



2.3.5. Conversion factors

Conversion factor from standing volume (SV) to a cutting volume (CV), based on the assumption above: CV = 0.77 X SV

Conversion factors from volume unit to weight unit at basic density:

1 m^3 under bark = 0,584 ton

Conversion factors from wood weight to CO_2 tons: 1 ton of wood at basic density = 0,5 ton of carbon = 1,835 ton of CO_2

Conversion factors from carbon to cubic meter: 3.425

2.3.6. Data delivered to M1

Indicator	Ind. unit	Clear cut with large single-grip harvester	Harvesting of planted eucalyptus with medium single-grip harvester	Felling with large harvester	Forwarding of pine after: thinning	Forwarding of pine after: felling	Harvesting of coppice eucalyptus with small single-grip harvester	Final measuring, grading and sorting
Process ID		1000003	1000030	1000034	1000046	1000058	1000070	1000073
LI02a -	EUR		8,5				8,5	

Production cost - raw materials from FWC								
LI02c - Production cost - labour costs	EUR	1,14		2,38	1,64	1,51		
LI02d - Production cost - energy costs	EUR	0,81		1,67	1,12	1,04		
LI02e - Other productive costs	EUR	0,04		0,18	0,12	0,06		
LI02f - Non-productive costs	EUR	1,88		3,89	1,46	1,36		
LI09a - Employment male	perso n hour	0,05066	1593702	0,067	0,072654	0,067	1062468	
LI09b - Employment female	perso n hour	0,00495	16098	0,007	0,007103	0,00655	10732	
LI09c - Employment urban	perso n hour	0,04531	1794000	0,094	0,064998	0,05993		
LI09d - Employment rural	perso n hour	0,01029	7898615	0,021	0,014759	0,01361		
LI10a - Wages and salaries male	EUR	1,14	1,26	2,38	1,64	1,51	1,26	
LI10b - Wages and salaries female	EUR	1,14	1,14	2,38	1,64	1,51		
LI13.2.b - Energy use (non-renewable)	MJ	26,5	1,4	54	38,3	36	1,4	
LI14.2.e - Carbon sequestration in harvested wood products	tons of C	0,24	1,07164	0,24	0,24	0,24	1,07164	
LI14.1 - Greenhouse gas emissions per process	kg GWP 100	2,51	0,004218	5,12	3,63	3,44	0,001534	
LI11.1.a - Occupational accidents (non-fatal) - absolute numbers	cases	2,5E-07	2,82E-06	2,5E-07	2,5E-07	2,5E-07	2,82E-06	
LI11.1.b - Occupational accidents (non-fatal) - % per 1000 employees	cases	0,004	0	0,004	0,004	0,004		0
LI11.1.c - Occupational accidents (fatal) - absolute numbers	cases	2,5E-08	6,62E-13	2,5E-08	2,5E-08	2,5E-08	6,62E-13	
LI11.1.d - Occupational accidents (fatal) - % per 1000 employees	%	0,07	0	0,07	0,07	0,07		0
LI11.2.b - Occupational diseases - % per	%	0,3	0	0,3	0,3	0,3		0

1000 employees								
LI19.3.a - Non-greenhouse gas emissions into air - SO2	g	2,14		4,37	3,1	2,91		
LI19.3.b - Non-greenhouse gas emissions into air - Nox	g	32,3		65,7	45,9	43,1		
LI19.3.c - Non-greenhouse gas emissions into air - NMVOC	g	5,61		11,4	8,11	7,62		
LI19.3 - Non-greenhouse gas emissions into air - NH3	g	1,71E-06		3,49E-06	2,48E-06	2,33E-06		
LI24.1.b - Persons employed - high skilled workers	person hour	0,0556	0	0,116	0,079	0,074		0

Indicator	**Ind. unit**	**Transport by truck with crane**	**Forwarding by medium forwarder (12 tons)**	**Transport by 60t truck with crane acc to assortment**		**Final measuring and sorting acc. to quality at pulpmill**	**Final measuring and sorting acc. to quality at pulpmill**	**Pre-commercial thinning of 6-7 shoots per stool on second and third rotation**
Process ID		1000074	1000080	1000102	1000104	1000109	1000118	1000136
LI02a - Production cost - raw materials from FWC	EUR	0,148	5					150
LI02c - Production cost - labour costs	EUR			0,024505	0,024505	0,29	0,29	
LI02d - Production cost - energy costs	EUR			0,029194	0,029194	0	0	
LI02e - Other productive costs	EUR			1,08	1,08	0	0	
LI02f - Non-productive costs	EUR			0,023087	0,023087	0	0	
LI09a - Employment male	person hour		2656170	0,004225	0,004225	0,0138	0,0138	1062468
LI09b - Employment female	person hour		26830	0,000375	0,000375	0,001364	0,001364	10732
LI09c - Employment urban	person hour			0,003772	0,003772	0,012427	0,012427	
LI09d - Employment rural	person hour			0,00083	0,00083	0,002728	0,002728	
LI10a - Wages and salaries male	EUR	0,03	1,14	0,052	0,052	0,29	0,29	
LI10b - Wages and salaries female	EUR	0,03		0,052	0,052	0,29	0,29	
LI13.2.b - Energy	MJ	1,075	1,22	1,075	1,075	0	0	0,55

use (non-renewable)								
LI14.2.a - Carbon sequestration in woody living biomass (above ground)								1,07164
LI14.2.e - Carbon sequestration in harvested wood products	tons of C	0,215	1,07164	0,24	0,24	0,24	0,24	
LI14.1 - Greenhouse gas emissions per process	kg GWP 100	9,13	0,0026	0,0982	0,0982	0	0	0,001534
LI11.1.a - Occupational accidents (non-fatal) - absolute numbers	cases		2,51E-06					2,26E-05
LI11.1.c - Occupational accidents (fatal) - absolute numbers	cases		5,23E-13					4,24E-11
LI15.1.a - Transport distance - road transport		93		93	93			
LI15.2.a - Freight volume - road transport		9689473		2970792	2040603			
LI19.3.a - Non-greenhouse gas emissions into air - SO2	g			0,0822	0,0822	0	0	
LI19.3.b - Non-greenhouse gas emissions into air - Nox	g			0,761	0,761	0	0	
LI19.3.c - Non-greenhouse gas emissions into air - NMVOC	g			0,218	0,218	0	0	
LI19.3 - Non-greenhouse gas emissions into air - NH3	g			0,000226	0,000226	0	0	
LI24.1.b - Persons employed - high skilled workers	person hour	0	0	0,080843	0,080843	0,015154	0,015154	

3 Perspective/further work

After this first experience from the test chain, most of the assumptions and conversion factors are set. This will lead to further work on embedded single chains within the respective case studies. For this work the entire set of general indicators (Set 5) will be used. This work will be mainly carried out in the EFORWOOD Client, provided by M1, IFER.

4 Literature

Project-intern literature:

Rametsteiner, Pülzl, Puustjärvi. EFORWOOD Indicator Draft Set 4 (2006)

Rametsteiner, Pülzl, Puustjärvi. EFORWOOD Indicator Draft Set 5 (2006)

Trasobares, Lindner, Suominen. D1.4.3 Description of modelling framework (2007)

www.eforwood.com

Berg, Staffan. 2006, D3.2.3. SI-data for harvesting operations based on PD3.2.1 and PD3.2.2. Deliverable from Module 3. www.eforwood.com

Wilhelmsson, L. Arlinger, J. Moberg, L. 2006. Examples of bucking simulation including prediction of properties based on input data from Swedish National Forest Inventory, and TimAn and Pri-analyses software. Internal document Wp 3.1. 2006-09-15. 10 pp.

Project-extern literature:

European Commission (2005). Sustainable Development Indicators for the European Union. Luxemburg: Eurostat.

Kirkpatrick, C., and C. George. 2005. Sustainability impact assessment of proposed WTO negotiations. Overall project final report for sector studies: agriculture, distribution services, forests.

Mendoza and Prabhu, 2002. Multidimensional measurements and approaches to forest sustainability assessments, in: Pukkala, T. (Ed.), Multi-objective forest planning, Kluwer Academic Publishers, The Nederlands, pp. 71-98.

MCPFE (Ministerial Conference on the Protection of Forests in Europe) 2002. Improved Pan-European Indicators for Sustainable Forest Management. MCPFE Expert Level Meeting 7-8 October 2002, Vienna, Austria.

Erik Eriksson and Staffan Berg. 2007. Implications of environmental quality objectives on the potential of forestry to reduce net CO_2 emissions ? a case study in central Sweden.Forestry, April 2007; vol 80(2): 99 - 111

Brunberg, T., 1995. Basic data for productivity norms for heavy-duty single-grip harvesters in final felling. The Forestry Research Institute of Sweden, Redogörelse nr 7, Uppsala. pp. 22 (In Swedish with summary in English).

Brunberg, T., 1997. Basic data for productivity norms for single-grip harvesters in thinning. The Forestry Research Institute of Sweden, Redogörelse nr 8, Uppsala. pp. 18 (In Swedish with summary in English).

Brunberg, T. 2004. Productivity-norm data for forwarders. The Forestry Research Institute of Sweden, Redogörelse nr 3, Uppsala. pp. 12 (In Swedish with summary in English).

Hannrup, B. 2004. Functions for estimating of bark thickness of Scots pine and Norway spruce by CTL harvesters. Swedish title: Funktioner för skattning av barkens tjocklek hos tall och gran vid avverkning med skördare. Work report 575. Skogforsk, Uppsala. pp 1-33. (In Swedish).

Lamlom, S H. Savidge, R A. 2003. A reassessment of carbon content in wood: variation within and between 41 North American species. Biomass and Bioenergy 25. pp 381-388.

Marklund, L.G., 1988.Biomass functions for pine, spruce and birch in Sweden. Swed. Univ. Agri. Sci. Dept. of Forest Survey. Umeå, Sweden. Report 45. pp. 73. (In Swedish with summary in English).

Ogemark, T. & Arlinger, J. 2003. TimAn 2.0 (Timber Analyses), 2003-03-17. Users guide. Swedish title: Användarhandledning. Skogforsk, Uppsala, 11 pp. (In Swedish).

Wilhelmsson, L. 2006. Two models for predicting the number of annual rings in cross-sections of tree stems. Scandinavian Journal of Forest Research 21, Supplement 7, pp 37-47.

Wilhelmsson, L. Arlinger, J. Spångberg, K. Lundqvist, S-O. Grahn, T. Hedenberg, Ö. Olsson, L. 2002. Models for Predicting Wood Properties in Stems of *Picea abies* and *Pinus sylvestris* in Sweden. Scandinavian Journal of Forest Research 17:4, pp 330-350.

Wilhelmsson, L. Moberg, L. 2004. Volume weights of green logs. Predicted mean values and deviations based on models and scaling statistics. Swedish title: Viktsutredning - Råvolymvikter. Prognos för medelvärden och spridningsmått med hjälp av beräkningsmodeller och vägning vid mätstationer. Work report 569. Skogforsk, Uppsala. pp 1-35. (In Swedish).

Anon 2005. Swedish Statistical Yearbook of Forestry 2006. National (Swedish) Board of Forestry. Official Statistics of Sweden. Jönköping. www.svo.se/statistics ; SYS 2006

Anon 2005 Statistcal Yearbook of Sweden 2006, Statistiska Centralbyrån. Official Statistics of Sweden. Stockholm www.scb.se; SSY 2005