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WP 3.2: Harvesting

Set of data for harvesting processes to be put into ToSIA at case study and European case level

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Background

Within the ToSIA development framework (Lindner et al. 2009) there have been efforts to collect data from forest operations, especially logging operations (the harvesting and hauling of timber to roadside). The identification of processes and the collection of data were pursued by partners in the Eforwood program. In order to provide ToSIA with data about logging operations, data were collected during two fundamental aspects of the Eforwood project: i) to supply a set of case studies with data (Baden Württemberg case, Iberian case and Scandinavian case) and to ii) supply data about logging operations that reflect conditions in the 27 countries of the European Union.

To facilitate an organised collection of data for a selected numbers of indicators, the Eforwood Data Collection Protocol was developed PD 0.1.16 (Eforwood, 2008b). Some of these indicators values concerning the year 2005 will be highlighted in this paper. They relate to the possible environmental, social and economic impacts of forest operations.

Objectives

The aim of this work is to report the principles and methodology behind the collection of indicator values for the modelling of the Forest Wood Chain (FWC) from harvesting processes to road side prior to transport to mill gate operations in the Module 3 area of work, Working Package 3.2 Harvesting Operations.

Scope

These sections of Forest Wood Chains (FWC) which concern the timber harvesting and forwarding processes have been modelled for a number of geographical areas, namely:

Area	Name
Baden Württemberg in Southern Germany	Baden Württemberg case (BW case)
Västerbotten in Northern Sweden	Scandinavian case
Aquitaine in France, Spain and Portugal	Iberian case
Most of the member states in the European Union	European Forest Wood Chain (EU FWC)

Reference futures A1 and B2

The modelling of chains and assigning of indicators were made for the base year 2005. Thereafter, the two reference futures 2015 and 2025 were applied. Reference futures are dynamic 'benchmark' scenarios, but without major policy interventions (Deliverable D 1.4.7), (Eforwood, 2008f).

In 1996 the IPCC (Intergovernmental Panel on Climate Change) decided to develop a new set of emission situations that are described in the Special Report on Emission Scenarios (SRES). This set of scenarios is now known as the SRES scenarios, which were used by the IPCC for their third and fourth assessments. The scenarios are mostly developed for energy system parameters and related emissions. The underlying four reference futures, however, provide consistent storylines on the development of drivers like population growth and economic development in the future. Of the set of four SRES reference futures only the two contrasting A1 and B2 storylines were used within Eforwood.

Consequently, next to the "Baseline 2005" the following reference future were applied:

- Reference future 2015 A1
- Reference future 2015 B2
- Reference future 2025 A1
- Reference future 2025 B2

Scenarios

Because driving forces can take different directions, it is important to develop multiple baseline scenarios. In Eforwood, four scenarios were attached to the reference futures (Eforwood, 2008f). They are related to the IPCC modelling (IPCC, 2000). Furthermore, internal Eforwood scenarios (Laurijssen & Usenius, 2008) were created for technological and commercial development.

Three scenario areas were decided within Eforwood, each for one regional case. In addition one scenario was chosen for the EU scale case. The following scenarios were adopted:

- Forest conservation scenario to be applied in the EU FWC
- Bio-energy scenario to be applied to Baden Württemberg case study
- Technology change scenario to be applied to Scandinavian case Study
- Consumption change scenario to be applied to the Iberian case Study

Method of data collection

In order to facilitate practical data collection and interpretation in the EU FWC, countries were grouped according to the Table 1 below based on PD 3.4.6 (Eforwood, 2008g); also see Fig. 1.

Table 1. Country regions and species in use for data collection at EU FWC level country/region.

Country Region	Countries	Partners responsible for data collection and processing
CEU: Central EU25+2 :	Germany, Austria, Benelux, Denmark, Switzerland, France, Italy	ALUFR, FCBA ,FVA
NEU: Northern EU25+2	Sweden, Norway, Finland, British Isles, Estonia	FR, Skogforsk,
SEU: Southern EU25+2 :	Cyprus, Greece, Malta	FCBA
EEU Eastern EU25+2:	Czech Republic, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia, Romania	ALUFR, FVA, Skogforsk
IBERIAN:	Portugal, Spain	FCBA

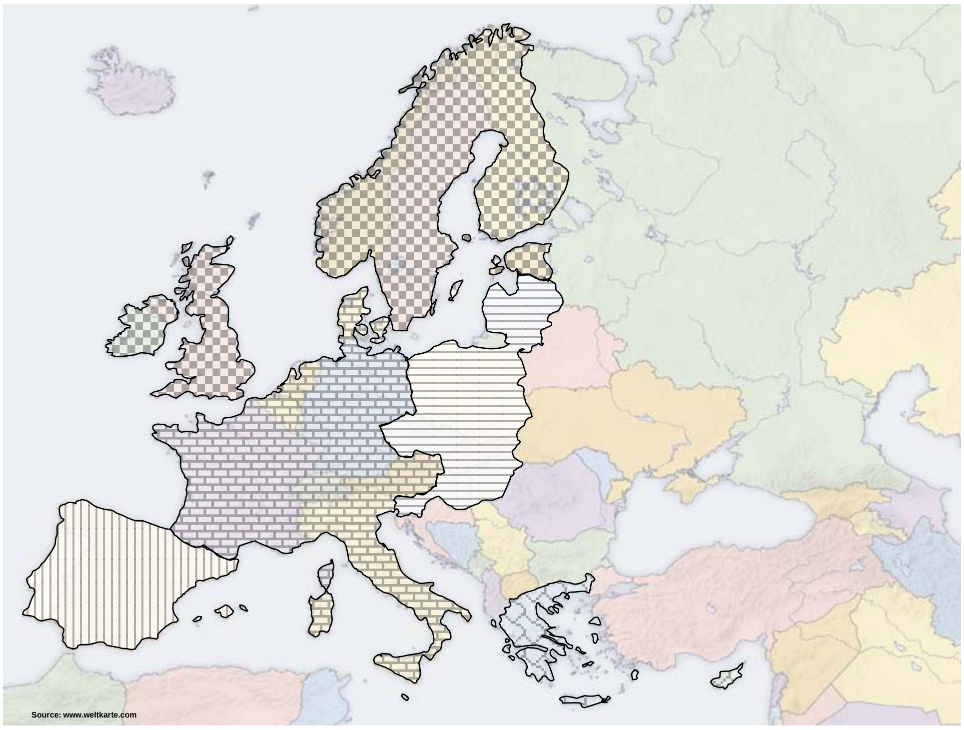

Figure 1. Map of country groups represented in the European Forest Wood Chain

The pooling of the countries has been conducted with regard to different aspects. These facets are the affiliation to a certain biogeographical province, the comparableness in the tree species composition, the comparableness in the structure of the processes and the comparableness in the level of mechanisation of the processes of timber felling and timber hauling, D3.4.7 (Eforwood, 2009b).

The boundaries of the processes in the FWCs were set from the point where machines are brought to the actual working site and until the harvested timber is loaded at landing at roadside. This means that transport of personnel and equipment is not included in the data set. When calculating indicators, the boundaries vary depending on the perspective of the different indicators. This is further defined in (Eforwood, 2008b).

General Methodology

Indicators

The development of indicators is a result of several years work in the international arena. For example, the United Nations' processes emerged from UNCED (UN, 1987), EU (MCPFE; 2007) ISO (International Organization for Standardization) and the different systems that are used for forest certification e.g. FSC (Forest Stewardship Council) or PEFC (Programme for the Endorsement of Forest Certification schemes). A detailed description of the different types of indicator sets, are in Eforwood D 1.1.1 (Eforwood; 2006a).

The work in Eforwood broke the various sets of indicators down and made it possible to be utilised in the ToSIA effort. As a result, a joint list of relevant indicators has been developed, refined and eventually applied to the case studies (Eforwood, 2006b and; Eforwood, 2009b).

Modeling approach

Each FWC is described as a number of interconnected processes such as e.g. mechanized harvesting and forwarding of logs to the roadside. The sustainability indicators are connected to the processes.

Indicators are reported in units specific to the Module. Within Module 3 (harvesting, forwarding and hauling processes), all indicators are related to the reporting (product) unit m^3ub. The development and description of processes were done in the early stages of the Eforwood project and are published in Deliverable 3.2.3 (Eforwood, 2008a,)

Data collection was done according to three different approaches:

i) Specific and empirical, which means data was collected from organisations or "follow–up" routines

ii) Generic or derived, which means that data was extracted from National or European statistics and

iii) Model based data

iv) Expert estimated data.

The data collected for the case studies and the EU FWC were a mixture of these approaches and varied between different countries. It was necessary to combine data from different sources, and weighting and scaling was used in this process. Calculation procedures, such as modelling of operations, were done in PD3.2.4 and PD3.2.5 (Eforwood, 2008d;, Eforwood, 2008e). Used models, statistics and other data sources are presented in tables 2 and 3. In the following the procedure is described and detailed for each case study.

Table 2. Meta data for input data concerning logging operations in the case studies

Case Studies	Countries	Models	Statistics	Miscellaneous
Baden Württemberg case study	GER	Holzernte, FVA(2007)	Entrepreneur Association	Experts: FVA, ALUFR
Iberian Case Study	FRA	Procou	Mutualité social agricole, Agreste EAB	Experts: FCBA, University of Madrid, USC Lugo.
Scandinavian Case study	SWE	Skogforsk Hallonborg (2000)	Official Statistics of Sweden (2006)	Experts: Skogforsk.

Table 3. Meta data for input data concerning logging operations for countries in the EU FWC

EU FWC	Countries	Models	Statistics	Miscellaneous
CEU: Central EU25+2	GER, AUT, BNL, DKK, HEL, FRA, IT	As in BW Case	National Statistics, Eurostat, NFI, branch statistics	Expert interviews
NEU: Northern EU25+2	SWE, NOR, FIN, UK, EST	As in Scandinavian case	Eurostat, National statistics,	Experts, FIN, SLO, DKK, EST, UK
SEU: Southern EU25+2	Cyprus, Greece, Malta		- for Malta and Cyprus no specific data existing for harvesting process, - due to high difficulties to collect harvesting data for Greece, data were considered as not relevant.	Expert interviews
EEU: Eastern EU25+2	Czech Republic, Hungary, Latvia Lithuania, Poland, Slovakia, Slovenia, Romania	Calculation routines See D.3.4.7	As far as available national statistics See D 3.4.7	Expert interviews via questionnaires and telephone conversations; national forest holdings
Iberian	Spain, Portugal	As in Iberian case	National Statistics	Expert interviews

Data reporting is related to the reporting unit of the process; however, the overall flow in ToSIA is calculated as mass of carbon, (Eforwood, 2006b).

Therefore, in each case study there was a defined conversion factor used to transform a reporting or product unit to carbon per chain (Table 4.). In the EU FWC, these conversion factors were defined for the whole chain and are not cited here.

Table 4. Conversion factors in case studies

Conversion factor for Product unit- m^3 under bark (ub)	Baden Württemberg Spruce	Baden Württemberg Beech	Iberian Maritime pine	Iberian Eucalyptus	Scandinav-ian all species
Product unit to ton (fresh weight)	0,79	1,025	0,70	0,584	0,97
Product unit to carbon	0,2105	0,3098	0,16	0,2251	0,2508

The input data sets have been refined to address both the reference futures and scenarios by principally two approaches:

i) an extrapolation according to trends set in the scenario descriptions (Eforwood, 2008; Laurijssen & Usenius, 2009) and

ii) an extrapolation according to technical interpretation concerning the impact of a certain change for harvesting and forwarding. The former was for logging operations adjusted to processes with the aid of an Excel based tool (Fischbach et al., 2009). The latter was performed by each partner organisation according to the conditions of each country.

Case studies

1. Iberian case study – France, Spain and Portugal

Structure

In France, 15,5 million hectares of forests cover 28,6 % of the metropolitan territory (France is ranked third in Europe). French forests consist primarily of broadleaved trees (70 % of the forested area are pure and mixed stands) and conifers are more often present in the Landes Forest and in the mountainous regions (IFN, 2008). The average mechanized harvesting rate in France is 24 % (Laurier, 2005) and the average harvested volume is 37 million of cubic meters in 2007 (Ministère de l'agriculture et de la pêche, 2009).

The Iberian Pensinsula region includes the political boundaries corresponding to the countries of Spain, Portugal and South of France. Maritime pine and Eucalyptus are the two most important tree species in this region. For example, Pinus pinaster represents 57 % of the annual harvest in the Atlantic Arc (more of half of the harvest is focused in the French region, France) and Eucalyptus represents 27 % of the annual harvest localised in Portugal and North of Spain (IEFC, 2002). Iberian Forestry is managed according to the principle of even-aged forestry. The main part of the harvested forest is composed of an intensive even-aged stands. Complete mechanized harvesting systems are used, as are different types of harvesters and forwarders (Eforwood, 2008d). The main parts of harvesting operations are felling (thinning and clear-cut) and forwarding of roundwood (shortwood*).*

For Eucalyptus, characteristics for harvesting operations are described as follows *(*Eforwood, 2008d): first harvesting is mechanized for planted areas, second or third harvestings is coppicing using either motor manual felling (when the logging is difficult for harvester) or mechanized cutting with medium harvester (which is becoming the dominant system in the Iberian Pensinsula). Indeed, *t*he mechanized harvesting rate in Spain is 60 % (Eforwood, 2007). Iberian eucalyptus forest covers 1,200,000 ha and the harvested volume is about 8 million cubic meters. The rotation period is between 12 and 20 years (Celpa, 2005 ; Tolosana et al., 2004).

Maritime pine is planted and managed with intensive even-aged forestry. The rotation length is between 40 and 50 years and the final harvest system is clear cut. FCBA has been working since the 1960s on a maritime pine improvement programme. In Aquitaine in 2007, the harvested volume was 9 million cubic meters which represents 24 % of the French harvest (Ministère de l'agriculture et de la pêche, 2009). About 8 million cubic meters of maritime pine are harvested each year in the Landes de Gascogne. The mechanized harvesting rate to harvest maritime pine is 72 % for clear cut operations and 93 % in thinning operations with small and medium harvester (Emeyriat, 2009). Maritime pine is principally harvested in shortwood and the forwarding process is realised with forwarder.

Processes

The M3 processes of maritime pine from harvesting process to forwarding process are described in below (see the following Figure 2).

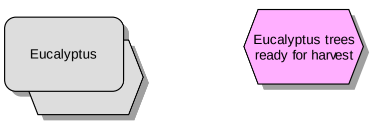

Figure 2. Logging and forwarding processes in the Iberian Chain

The quantity of harvested volumes of Maritime pine is demonstrated in below (see Table 5). The harvested total volume in 2005 (study from branch statistics) is 8,144,000 m^3 ob. The total harvested volume share of the total standing volume is 5.6 %.

Table 5. France. Average volumes harvested per machine type, assortment and its shares

Harvested volume	Large harvester	Medium harvester	Small harvester	Medium Forwarding	Large Forwarding
Pulpwood, m^3ub	408 096	1 107 478	625 452	1 732 930	408 096
Saw log, m^3ub	2 040 481	1 740 323	125 090		
Harvest residues, m^3ub	272 064	316 422	83 394		
Pulpwood, %	15 %	35 %	75 %	55 %	15 %
Saw log, %	75 %	55 %	15 %	35 %	75 %
Harvest residues;%	10 %	10 %	10 %	10 %	10 %

The pulpwood harvested volume in Portugal is about 2 683 000 m^3ub (PD 3.4.2) (Eforwood, 2007) and in Spain this volume is about 3 341 000 m^3 ub. We assume the harvested volume for each rotation is the same. The quantity of harvested volumes of Eucalyptus is demonstrated in Table 6 Iberia.

The product share is the same between planted eucalyptus and coppice eucalyptus after harvesting. The harvested volume is divided in two parts: pulpwood logs and harvester residues. The pulpwood logs represent 77 % and the harvest residues (bark, leaves, branches, and stem < 7 cm) represent 23 %. We assume that debarking is done at the felling site.

Table 6. Iberia. Average volumes harvested per machine type, assortment and shares.

Harvetsed Volume	Medium harvester	Small harvester	Medium Forwarding
Pulpwood, m^3ub	1 546 136	1 546 136	4 638 408
Harvest residues, m^3ub	461 833	461 833	
Pulpwood, %	77 %	77 %	77 %
Harvest residues, %	23 %	23 %	22 %

Special case related remarks on methodology

a) Models

The cost model used is the Procou Model, developed by AFOCEL in the 1990s. It was used for the partial modelling of the harvesting and forwarding processes in the Iberian case study. The

Procou model assesses the operational cost of different harvesting equipment (power saw, harvester and forwarder). This software attains the operational cost based on the machine productivity. These costs can be presented with different units depending on time measurement

b) Statistics

Indicator data were attained through the use of:

- Official statistics which were used to collect statistics on accidents);
- Branch statistics concerning statistics from government on forest and the harvested volume of wood;
- Experts' judgement (FCBA, Tolosana from University in Madrid, Roque from USC in Lugo);
- Data from experiments;
- Weighting or scaling factors relevant for adaptation of generic data to specific data for the actual case.

2. Baden Württemberg case study

Structure

The harvesting and logging systems in the Baden-Württemberg case study were applied at a regional level and aimed to describe the network of forestry-wood chains in the region, including imports and exports. The total area of this region comprises 3.6 million ha, out of which approximately 1.4 million ha (38.1% of the total area) are forested. The forest cover consists of mainly even-aged stands, however, within the last decade conversion to more broadleaved tree species and more structured stands is occurring. At present, the main tree species are Norway spruce (*Picea abies*) with approximately 551 000 ha (39% of all tree species) and European beech (*Fagus sylvatica*) with approximately 289 000 ha (21%) (MLR BW, 2007). This region represents the Central European forestry-wood-chains which are characterised by a large variation of forest types with diverse silvicultural management, stands with mixtures of broadleaved and conifer species, and a wide age range of stands. This highly diversified forest production results in a highly diversified wood-based industry with a heterogeneous structure in mill size with a degree of specialisation in production as well as in a multitude of linkages between the different industries.

For this study, only Norway spruce (*Picea abies*) and European beech (*Fagus sylvatica*) were considered since these two species account for more than 2/3 of wood volume produced and processed in Baden-Württemberg. The total harvested volume in the reference year 2005 was 9.1 million m^3 roundwood under bark (softwood 7.1 million m^3, hardwood 2.0 million m^3) (STALA BW, 2007). Harvested wood was provided as long, full length logs (poles) and short logs for sawmilling, short logs for board production, logs for mechanical pulping, chemical pulping, and wood for bioenergy production.

Forestry and the wood-based industry contribute about 7 % to the GDP in comparison to 2% on an all-Germany level.

Processes

According to Forbrig, A. (2004), decisions about the harvesting process generally depend on the diameter of the trees and on the terrain. Three primary classes of harvesting systems can be identified: motor-manual, partly mechanised and fully mechanised. For this case study, only fully mechanised and motor-manual systems were considered. Related to the decisions within the harvesting systems is the type of the desired harvested product; full length logs were regarded as the main product of motor-manually felled trees, and the products of fully mechanised harvesting systems are short logs for sawmills and pulpwood. In Baden-Württemberg, most of the wood is harvested during thinning operations (approximately 90%), final cutting is mostly targeted tree selection (MLR BW, 2007). Machines are only operating on skid-roads at distances of 20m (or 40m for partly mechanised systems, but not applied in the context of this investigation), depending on the soil conditions. The appropriate harvesting system was selected accordingly depending on tree species, tree size, and slope. The relevant harvesting systems are listed in Table 7.

Table 7. General harvesting systems in Baden-Württemberg that were applied in the case study

Diameter (breast hight) of harvested trees	slope		
	<= 30% (striproads interval 20/40 m)	30-60% (accessible by road)	>60% (not accessible by road)
<= 35 cm	**harvester/ forwarder** harvester/ forwarder and midfield operations with chainsaws	**Motormanual harvesting, forwarding with skidders**	**Motormanual harvesting, forwarding with cable cranes**
> 35 cm	**Motormanual harvesting, forwarding with skidders**	**Motormanual harvesting, forwarding with skidders**	

All forest privately owned, which is smaller than 10h on level terrain was allocated to motormanual felling to account for the realistic harvesting systems (Forbrig, A., 2004).

a) Motor-manual system

As ascertained by Forbrig, A. (2004), in motor manual systems the selected trees are felled, debranched and topped by chainsaw. Forwarding is done for the full length logs with a skidder to the forest road. At the road side, saw logs (usually full length logs up to 21m long from the lower part of the tree; additional short logs when tree dimension allows a top diameter above 12cm; type and number of saw logs depend on the length of the stem and on the customer demand) as well as pulpwood are cross cut. Timber is measured and its grade is classified. The used machinery is a medium size chainsaw (3.1 – 4.0 kW; bar length 45 cm) and a skidder with double winch wheel and crane. Products cut from spruce are full length logs, LDT (large dimensioned timber), short (standard length) saw logs, pulpwood, firewood, and residues.

Products cut from beech are full length logs, short standard logs, veneer logs, pulpwood, firewood and residues.

b) Fully mechanised system

The precondition in fully mechanised systems is the existence of skid-roads at distances of not more than 20 m, as demonstrated in Forbrig, A. (2004). Trees that are selectively felled are debranched and cut-to-length into short saw logs (standard length 5m) and pulpwood (depending on quality and on the diameter of the tree). The measurement of the logs is done by a single grip harvester, which runs on skid-roads. Forwarding and stacking of the logs is carried out at the forest road side by forwarder. Machines used are a medium single grip harvester (101-170 kW, 12-20 t) and a medium forwarder (10-13 t). The products are short logs, pulpwood and residues, cut from both spruce and beech.

c) Processor tower yarding (Whole tree) on very steep terrain

As described in Raab, S. et al. (2002), trees are felled and topped by chainsaw. The timber is forwarded as whole trees to the forest road by the yarder, and are debranched and cut to assortments by processor unit. Machines used are medium chainsaw (3,1 – 4,0 kW; bar length 45 cm) and a wheeled tower yarder with mounted processor unit. The products are short saw logs, pulpwood and residues.

d) Harvesting systems for bioenergy /wood chipping

Remler et al. (1999) described that bioenergy from forest residues (tops, branches, off-cuts) can be produced in the following harvesting alternatives in spruce and beech stands: flat terrain (<30% slope) as follow-up activity after motor-manual, partly mechanised and fully-mechanised harvesting. The wood for bioenergy will include all parts of the tree which are not suitable for industrial processing; alternatively, wood for bioenergy will also substitute the shares of short log considered for pulp production. Common harvesting systems are used to cut the trees. Crown material is forwarded to the forest road by forwarder and the material is chipped at roadside into containers. Machines used depend on the harvesting system. Typically, a medium-sized wood chipper mounted on truck or trailer is used. The products are forest ("green") chips.

Table 8. Characteristics for Baden-Württemberg harvesting and logging systems as considered in the case study (Forbrig, 2004).

		Operation	Equipment	Type of fuel used	Person nel	Product
Pre-commercial thinning	Cutting in young spruce stands	moving between sites, removing of small trees	any vehicle power saw	petrol or diesel EU class (1-3)	one operator	on site treated ha/m
Harvesting chains: *Motor manual chain*	Motor manual felling	moving between sites felling of trees debranching cross cutting	any vehicle power saw	petrol (1–2) or diesel EU class (1–3)	one operator*	on site whole trees whole stem to pole length at top D>8 cm
Harvesting chains: *Motor manual chain*	Forwarding & cross cutting	moving between sites skidding on base road cross cutting sorting to quality	skidder/trailer double winch wheel skidder power saw, skidder	petrol or diesel EU class (1–3), lubes	one operator	on site: pole length trees, changed location pole length tree, top>12 cm, max 20m length; side product: short logs (pulp & paper; panels; bioenergy); sorted logs at roadside according to size and grade
Harvesting chains: *Mechanised Cutting*	Mechanized cutting Medium harvester	moving between sites felling debranching sorting to quality	forwarder/trailer medium harvester	diesel EU class (1–3), lubes	one operator	on site, felled tree whole stem logs
Harvesting chains: *Mechanised Cutting*	Forwarding Medium Forwarder	moving between sites forwarding on base road	forwarder/trailer medium forwarder	diesel EU class (1–3), lubes	one operator	on site, logs piled at roadside according to assortment size and quality

Special case related remarks on methodology

For the Baden-Württemberg case study, harvesting and logging chains as well as several sources were used to gather the sustainability indicator data. Sub-indicators in the production costs were calculated using the software package "Holzernte Kalkulationsprogramme für Holzernte und Holzvermarktung" vers. 7.1. "Holzernte" (FVA, 2007) is a comprehensive product that, apart from giving cost and performance data to forest operations, is a decision support system for harvesting processes. Furthermore, it supports marketing in general as it also provides input or input interfaces about forest stands and some end products. FVA machine costs were calculated by an excel-based cost calculation model of AfL Niedersachsen e.V. (2005), KWF (2006) and their calculation methods.

Economic and social indicators were collected and calculated on the basis of official statistics, branch statistics, expert judgements, process modelling and calculation tools or routines such as the transport tool which has been developed within the Eforwood project

Structure of Logging chains

Typically M3 processes of spruce and beech chains from harvesting to forwarding are described below (see Figure 3).

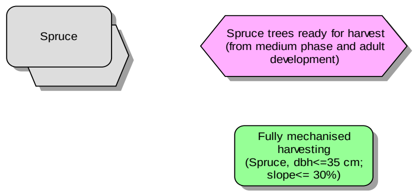

Figure 3. General structure of spruce and beech logging chains in Baden-Württemberg

The total harvested volume in 2005 was 9.1 million m^3ub. It was assumed in the modelling that 24 % of spruce was harvested with a fully mechanised system, while the other harvesting operations used motor manual systems The log assortments include short saw logs (top diameter >12cm) (58% of total biomass), pulpwood (11%), and harvest residues (26% remaining in the forest and 5% are further processed). 10 % of beech stands were stratified as “dbh >35 cm with a slope of 30-60%” and were harvested with a motor manual system as described above. A fully mechanised system was applied for beech stands (≤35 cm dbh, slope <30%). Any other beech stand was harvested using motor manual systems as described above. The log assortments over all applied systems are pulpwood (14%), 10% hardwood long logs, 27% fire wood logs and harvest residues (21% of the biomass remain in forest and 28% are further processed)

3. Scandinavian case study

Structure

The region that represents the Scandinavian Case consists 3.2 million hectares of managed forest, which altogether (2005) comprised a harvest of 7.8 million m^3ob standing forest (Eforwood 2008c). The area is defined by Västerbotten County in the north of Sweden. The forests in this area are mainly managed according to an even aged management with cuttings in final fellings and thinnings. The forests are dominated by area by conifers, indigenous Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea sbies*). Lodgepole pine, (*Pinus contorta*), a last century import from Canada, stands for some odd percents. Forest dominated by deciduous trees, birch (*Betula alba*) is approximately one quarter of the area. Apart from pure birch stands, the harvest volumes of birch emerge from forests in younger silvicultural stages and are removed in thinnings. The harvesting pattern for conifers is opposite and spruce is dominating by volume because it has higher stocking than pine forests.

The forest management were assigned to five basic silvicultural regimes;

1. Close to nature Scots pine - 18 % of forest land area
2. Close to Nature Spruce - 2 % of the forest land area.
3. Combined objectives Birch -1 % of the forest land area.
4. Combined objectives Mixed - 70% of the forest land area.
5. Intensive Even aged mixed - 9% of the forest land area.

There is a clear difference in climatic conditions and infrastructure between the coastal area and the interior. The area of the less climatic favourable Västerbotten interior is approximately 1,9 million ha and it has a higher dominance of spruce forests than the coastal area.

Table 9. Total potential volume of harvesting in different silvicultural stages for coniferous and deciduous species in Västerbotten. Eforwood (2008c).

Harvested volume	Final felling	Thinning	Pre commercial thinning	Other	Total
Coniferous m^3ob	5 015	1 847	81	204	7 147
Deciduous, m^3ob	208	318	111	25	662
Total m^3ob	5 223	2 165	192	229	7809

Processes in the Scandinavian case

This case includes the logging operations in a forest defined raw material driven case from forest to industry to end consumers. This report covers the logging processes and ends when roundwood processed to cut to length is delivered to road side. Eliasson (2005) demonstrated environmental impact of the forestry land use. Environmental aspects due to energy use of logging operations on the Scandinavian arena have been covered by Athanassiadis, (2000) and Athanassiadis et al (2000), Schwaiger et al. (2001), (Berg and Karjalainen (2003), Berg and Lindholm (2005), Lindholm and Berg (2005). Harvesting and forwarding stands for about 50% of the environmental load and is related to fuel use in the processes to mill gate operations.

The output (2005) from logging processes of roundwood in solid wood m^3ub delivered at road side for transport to mill gate is estimated to about 5 Million m^3ub (Table 10), of 2.3 million m^3ub saw logs and 2.7 m^3ub pulpwood. The harvest residues after final felling are a tentative source for bioenergy. In this application harvest residues (energy wood) are forwarded to roadside. This quantity and downgraded roundwood is comminuted at road side with a mobile chipper. In Reference futures and Technological scenarios. the use of stump harvesting is anticipated for even aged intensive forestry. These stumps are harvested with a stumpharvester and forwarded to roadside. Stumps are assumed to be comminuted at industry.

The logging of roundwood is fully mechanised and consists of harvester and forwarders (Eforwood, 2008a and c). This dual machine system has total dominance in the base scenario. It is used in all silvicultural regimes, with varying performance due to silvicultural stages and tree size. In Reference futures and Technical scenarios the advent of logging equipment in final felling that operate with immediate loading of the roundwood on the forwarding unit is anticipated. This leads to increased efficiency in logging. The harvesting of tops, branches and stumps for biofuel had a small importance in the base scenario. The general structure of the logging processes is demonstrated in Figure 4. The general approach for the collection and modelling of indicator values are described in the “General Methodology” section.

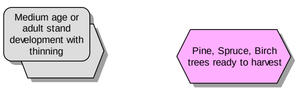

Fig. 4. General Structure of logging chains in Scandinavian case.

Table 10. Total l volume (1000 m^3ub) of delivered roundwood after harvesting and forwarding in the Scandinavian case(Eforwood ;2008c).

Roundwood delivered at road side for transport to mill gate	Conifers	Deciduous	total
Pulpwood, m^3ub	2 400	300	2 700
Saw log, m^3ub	2 200	0	2 300
Energy wood[1]			100
Total, m^3ub	4 600	300	5 100

4. European case Study

Structure

The European Union (EU) forest sector is characterised by a great diversity of forest types, forest cover, ownership structure and socio-economic conditions. In total, forests and other wooded land occupy in the order of 160 million ha or 35% of the total EU land area. Moreover, the EU is one of the largest producers, traders and consumers of forest products in the world. As a result of forestation programmes and the natural succession of vegetation, forest cover in the EU is increasing (European Commission, 2007).

The forest sector (forestry, and related industries) comprises the following industrial sectors: saw mills, the use of other forest-based materials; pulp, paper and paper-board manufacture; paper and paper-converting and printing industries. The annual production value of this sector was about 356 billion in 2001 and employed about 3.4 million people (European Commission, 2007; Garcia Gonzalez et al. 2009a and b).

The European Union 25 produced in total approximately 630 million of m^3ub 2004 (Official Statistics of Sweden, 2006). About 500 million m^3ub of this quantity is logging of industrial wood that is dominantly harvested by professional organisations. The European Forest-wood Chain is to reflect the impact of forestry on environmental, economic and social indicators as well as illustrate these impacts within Reference futures and Scenarios. The harvesting process is the first step in the Module 3 part of the chain and its development is assumed to have great importance on downstream processes.

Processes

As in case studies the processes involved motor manual felling with chainsaw, mechanized harvesting, hauling roundwood to the landing at roadside with forwarder, skidders and draught animals and to comminute energy wood with the aid of a chipper placed at roadside, Figure 5. An overview is presented in Table 11.

[1] Energy wood is mainly residues from Intensive managed even age chain, but also some downgraded roundwood.

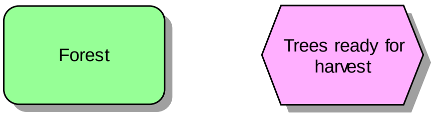

Fig. 5. General Structure of logging chains in European Forest Wood Chain. Although the silvicultural stages are similar for all countries studied, there is a wide variation in logging systems applied.

Table 11: Overview of logging process in the EU FWC

European Forest Wood Chain	Type of processes	Number of processes per country chain and remarks	
CEU: Central EU25+2	Mechanised and motor manual harvesting, hauling with forwarder or skidders, collecting and chipping of forest biomass.	4-8	
NEU: Northern EU25+2	Mechanised al harvesting, hauling with forwarder, collecting and chipping of forest biomass.	4-6	Motor manual harvesting only included in UK
SEU: Southern EU25+2			Not possible to find relevant data
EEU: Eastern EU25+2	Mechanised al harvesting, hauling with forwarder, collecting and skipping of forest biomass.	3-4	Master thesis by Fundel (2009) and Bürzle (2009).
Iberian	Mechanised and motor manual harvesting, hauling with forwarder or skidders, collecting and chipping of forest biomass.	3-6	Motor manual cutting only as preparing for harvester fellings.

With regards to the collecting of harvesting and forwarding data from British Isles and UK several sources were reviewed including reports from the Forestry Commission (1978; 2001) and Murgatroyd & Saunders (2005).

All countries in Eastern Europe (except Slovakia and Slovenia) were studied as part of a diploma thesis by the Buerzle (2009) and Fundel (2009). They were presented at the Albert-Ludwigs-University in Freiburg, Germany and are not further elaborated upon here because it has been reported in Deliverable 3.4.7 (see Eforwood, 2009b,).

For southern Europe (Malta, Cyprus, Greece) it was very difficult to collect data:

- Malta and Cyprus had no specific data existed for harvesting processes
- harvesting data for Greece was deemed as being nor relevant.

Hence it has been suggested from Module 3 that Greece data shall be deleted from the EUFWC.

Special issues on methodology related to EUFWC

Collecting data for all the countries have been a challenge and the methods used had to be accepted to what was feasible. When data were not present or available the research team developed simple and practical rules for the data collection. Throughout the data collection process, various rules were developed to be applied in specific cases according to Eforwood, (2009a).

When data for a specific country was missing, performance data from another country or region with similar traits or technology was used and all associated indicator values including: timber prices and costs were adjusted according to easily accessible statistical data as exchange rates for currencies (December 2005); Purchase Power Parities (2005) (Eforwood, 2008b); the costs for resources such as fuel and labour (Eurostat, 2009; Database Central Europe, 2007; Skogforsk, 2008); and other indicators can be adjusted with the use of relevant National Statistics (Category Agriculture and Forestry and Fisheries), as well as other sources (Baltic21 FOP5, 2002; Rådström& Thorsén, 2006).

In addition, calculated performance rates and costs were checked against expert opinions about costs and performance (Muiste, 2009; Piskur; 2009, Knaack-Nielsen;2009). In many cases, the exhaustion of all aforementioned methods did not yield any results. The procedure then was to find the dominant harvesting methods by expert guesses and consider its data as representative for that country. The procedure in conjunction to biomass harvesting was, if no other sources were available, to calculate data with the aid of FLIS2.0 (Skogforsk, 2008).Table 12 lists some important considerations.

Table 12: European Union. Examples on considerations taken in account when interpreting data for harvesting operations in the EU FWC

Countries	Reflected processes	Considerations
Sweden	Mechanized harvesting and forwarding. Bio fuel harvest.	As Scandinavian Case but reflecting operations in Central Sweden.
Norway, Finland Estonia, Latvia	Mechanized harvesting and forwarding	Based on Swedish productivity data adjusted to domestic prices on labour and other resources.
Denmark	Mechanized harvesting and forwarding, motor manual cutting and skidding	Based on German productivity data adjusted to domestic process on labour and resources
Slovenia	Mechanized harvesting and forwarding, motor manual cutting and skidding	Based on domestic and German productivity data adjusted to domestic prices and costs.

Adjusting and applying the indicator data to reference futures and scenarios has been described in the “General methodology” section. For the EU FWC, the impact on logging from the application of Natura 2000 was considered. The team of researchers in WP3.2 found that the greatest impact from the Natura 2000 scenarios is the available sites for timber harvest may decrease, therefore resulting in longer transport distance to mill. This is in fact not an issue for logging itself but for transport, thus outside the scope of this report. However, restrictions on logging methods might influence operations on a certain site. It was reasoned that many of these changes had already taken place in most of the northern and eastern European countries as the specification for Forest Certification (FSC and PEFC) has led these countries in the same direction. Such policy may also have impacts on the interaction between thinning and final felling processes. This was expected and indicators in such cases were adjusted accordingly. If there was no clear indication that a certain Natura 2000 level would result in changed technology or methods, no change in data input was made.

Results

At the time of writing this deliverable an intensive verification of indicator data was still ongoing. In order to illustrate the width of variations some chosen indicator values are demonstrated below (see Table 13 and Table 14). They reflect the case studies and European Union Forest-wood Chain for certain regions.

Table 13. Overview of variation of indicator values in case studies

	Scandinavian case		Baden Württemberg case		Iberian case	
Selected indicators	Harvesting (Logging) system					
	Spruce, 25% saw timber, thinnings	Spruce, 75% saw timber, final fellings	Fully mechanised felling and forwarder spruce dbh>35	Motor manual skidder, beech dbh>35	Harvesting; motor manual or Mechanised	Hauling Skidder, Forwarder Cable system
Wood value, €/m³	34.0	40.0	38.6	53.1	30	45
Production cost, €/m³	12.9	10.8	16.7	15.7	3–15	5–6
Energy use, Mj/m³	78	69	67	39	35–79	32–94
GHG, kg m3	7.4	6.4	5.9	4.9	3–7	2–4
Employment FTE/xm³	0.00015	0.00015	0.00025	0.00054	0.000041 – 0.00017	0.00005 – 0.00007
Tree size, m³	0.075	0.21	<= 35 cm	> 35 cm	0.1 – 1.5	0.25 – 1.3
Share final felling	0.00	1.00	0.056	0.032		
Terrain difficulty, verbal description	undulating	undulating	flat land, slope <= 30 %	hilly / undulating, slope 30–60 %	flat	flat
Components of operations	Dual machine system harvester forwarder	Dual machine system harvester forwarder	Dual machine system harvester forwarder	Medium chainsaw (3.1 – 4 kW; bar length 45 cm and kidder with double winch wheel and crane	Harvester or/ and power saw	Skidder or forwarder

Table 14. Overview of variation of indicator values in certain regions of the European Forest Wood chain

	CEU: Central EU25+2	NEU: Northern EU25+2		SEU: Southern EU25+2	EEU: Eastern EU25+2	IBERIAN	
Selected indicators	Logging system						
	Mechanised felling and forwarding	Mechanised felling and forwarding	Motor manual felling (felling with power saw and skidding or forwarder)	Motor manual and mechanized felling. Hauling by skidder or forwarder	Motor manual and mechanized felling. Hauling by skidder or forwarder	Mechanised felling and forwarding	Motor manual felling (felling with power saw and skidding or forwarder)
Wood value, €/m^3	42–71	37–41	65	n.a	26-71	30	45
Production cost, €/m^3	21–47	2.3 – 17.0	15–37	n.a	3.0-8.7	5–8	5 –10
Energy use, Mj/m^3	65 –110	46–60	33–83	n.a	44-84	56–94	18–94
GHG, kg m3	6 – 10	2–5	2–6	n.a	2-8	3–5	1– 6
Employment FTE/xm^3	0.006 – 0.009	0.00016 – 0.00042	0.00021	n.a	0.00022-0.00158	0.000055 – 0.000075	0.000086 – 0.00045
Tree size , m^3	n.a[1]	n.a	0.05 – 1.5	n.a	n.a	0.1 – 1.5	0.25 – 1.3
Share final felling	>50%	>50%	5%	n.a	n.a		
Terrain difficulty, verbal description	Undulating, hilly	Flat to hilly	Rough to steep ground	n.a	Flat to hilly	Flat land	Hilly terrain
Components of operations	Harvester and skidder, forwarder or cable crane	Harvester and forwarder	Motor manual felling, skidder or forwarder	For Malta and Cyprus no specific data exists for harvesting process. Data from Greece deemed as not relevant	Also winch systems for hauling	Harvester and forwarder	Motor manual felling, skidder or forwarder

[1]n.a- not available

Discussion of experiences

The data collection process is not completely finished due to the current data verification process. The final interpretation of data is still to come even if certain major trends come forward.

There is a distinguishable interval for reliability, especially when concerning production costs, energy use and machinery emissions. Experiences were gained in the course of data collection and these experiences can be shared to the reader.

This discussion is organised according to the following pattern:

a. economic indicators

b. environmental indicators

c. financial and social indicators

d. reporting unit and meta data

a) Economic indicators

Economic indicators are often quite stable and can be found from different sources such as statistics (European and National). There is actually an astonishing openness about economic information; therefore the economic reports from companies are good sources. If data are not at hand, then the figures can be determined through modelling techniques, the result of which can later be corroborated with the aid of other sources. Pragmatic comparisons can be made with similar systems. This was a very common approach in all case studies.

b) Environmental indicators

Environmental indicators can be accurately provided as long as they are related to technical issues (e.g. environmental impact of machine induced emissions). Otherwise, environmental indicators (e.g. biodiversity) are often difficult to relate to technical processes. Many of these indicators are collected within the European administrative political system, but are almost impossible to relate to technical processes although it is clear it has a long term effect. An example of such an indicator is effects on soils due to soil compaction from forest machines onsite. This effect was evaluated with the aid of a proxy, the share of logging site area that had a traceable impact of driving in forwarding.

c) Social indicators

Social data have demonstrated difficulties in data collection since it seldom has been collected in technical experiments as such. This kind of data is gathered in national and European statistics but is most often aggregated to a larger group as agriculture, forestry and fishery. In countries where forestry is important or there have been special efforts to follow the development of a certain trait, e.g. accidents, this data can be related to the reporting units or spent man-hours in the processes. A problem is here that it is not clear what actually is causing accidents in forest operations. Is it the amount of cubic meters produced or the specific time spent in the process? This is probably dependent on the work process itself, whether it is mechanized or motor manual. The attitudes of the operators and staff are important. Concerning the employment indicator, education etc there are similar problems. It is quite clear that the aggregated statistics cover more processes than are actually depicted in this Forest Wood Chain. We refer to the several support functions that are needed in order to bring machinery or personnel to the logging site, planning, costing and checking of work results. This means that the employment effect per reporting unit most probable is underestimated when the employment effect has been evaluated by time studies, overestimated when based on statistics?

Social indicators represent important sets of data to be recognized in the ToSIA and efforts should be spent on bringing this picture clear in a European context.

d) Reporting unit and Meta data

The reporting unit in the loggings chains is cubic metre solid volume under bark, m^3ub. But ToSIA refer to the carbon content. The density varies in forest wood chains; and its carbon content is reported as indicator values and we believe this has been done so careful as possible. It is clear the basic density has importance for the overall performance.

About Meta data can be said and repeated that the quality of data properties in this report are uneven. Some data is based on time studies of defined operations during certain conditions, other emerge from statistics and follow up and includes thus a wider circle of non defined ancillary operations. The third category is expert opinions formed by involved scientists. The data reflects the existing technical and social contexts and reflect therefore chains of varying maturity. Any repeated study of this topic might give different result for a certain chain but will likely be within the frame that is identified in this report.

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