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EFORWOOD

Tools for Sustainability Impact Assessment

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Thematic Priority: 6.3 Global Change and Ecosystems

Deliverable D1.4.6
Documentation of ToSIA developments up to month 23

Deliverable D1.4.5 version 2
Second prototype TOSIA-FWC
in open source for single chains

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EFORWOOD
Sustainability Impact Assessment of the Forestry - Wood Chain

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Deliverable D1.4.5 version 2
Second prototype TOSIA-FWC
in open source for single chains

AUTHORS:

Marcus Lindner
Tommi Suominen
Jordi Garcia
Taru Palosuo

European Forest Institute, EFI, Joensuu, Finland

WP 1.4. ToSIA - Tools for Sustainability Impact Assessment

Abstract:

The objective of the EFORWOOD project is to develop a decision support tool for Sustainability impact assessment of the European Forestry Wood Chains (FWC). ToSIA (Tool for Sustainability Impact Assessment) will be the predominant product of EFORWOOD. ToSIA will allow various end-users to analyse the sustainability effects of changes due to deliberate actions (e.g. in policies or business activities) or due to external forces (e.g. climate change, global markets).

In this deliverable report, the progress in ToSIA development since the release of D1.4.3 in February 2007 is documented. In addition, the application of the second ToSIA prototype to calculate sustainability indicators of Single FWCs is presented. The Single FWCs used in EFORWOOD are described and the procedure of calculating indicators values for the FWCs is explained. Furthermore, examples of initial results regarding the calculated sustainability indicators of these Single FWCs are presented. Attached to this report is the second ToSIA prototype, including instructions how to use the prototype.

Key words: decision support tool, indicator calculation, sustainability impact assessment, ToSIA prototype 2

Acronyms

C	Carbon
FWC	Forestry Wood Chain
GUI	Graphical User Interface
M2, M3, M4, M5	Modules 2,3,4 and 5 in EFORWOOD project
SIA	Sustainability Impact Assessment
ToSIA	Tool for Sustainability Impact Assessment

Executive Summary

Scope and purpose of the report

This combined deliverable report 1.4.6/1.4.5(update) presents ToSIA (Tool for Sustainability Impact Assessment), predominant product of EFORWOOD. ToSIA is being developed as a decision support tool for sustainability impact assessment of the European Forestry Wood Chain (FWC) and subsets thereof (i.e. selected Single FWCs and Case studies with multiple regional FWCs). ToSIA will allow various end-users, such as national and international policy makers, researchers and the forest-based industry, to analyse the sustainability effects of changes due to deliberate actions (e.g. in policies or business activities) or due to external/exogeneous forces (e.g. climate change, global markets).

The report aims to inform both the researchers in other subprojects as well as interested stakeholders and the general public about the progress of work on the sustainability impact assessment (SIA) approach in EFORWOOD. The purpose of this document is to present the latest developments in ToSIA methodology and to give an overview on the work that has been done up to month 23 of the EFORWOOD project. This report does not provide a comprehensive documentation of technical details of the ToSIA modelling framework, as this was already done in Deliverable D1.4.3. Moreover, a review of the results of two single chains, the forest-defined pine chain in Scandinavia and the regional-defined spruce chain in Baden Württemberg is presented.

Attached to the documentation is the second ToSIA prototype. In the Annex more technical details on the development of the second prototype are outlined, including instructions how to use the prototype. The prototype itself with more detailed documentation of the Java code is attached in the zip-archive.

Description of the ToSIA approach to Sustainability Impact Assessment of FWCs

The data required by ToSIA are stored in the EFORWOOD database, which also contains the predefined topologies of Forestry Wood Chains (FWC) that are studied in the project. Linked to the database is the EFORWOOD Database Client that allows EFORWOOD partners to enter data and design chains.

The SIA of the forest-based sector in EFORWOOD builds on the conceptual representation of FWCs as chains of value-adding processes. A FWC is understood in ToSIA as a dynamic structure linking production processes with input and output products. The FWC is characterized by a material flow entering and leaving each process. The amount of material that a process in a FWC handles is dynamically calculated based on the amounts of material that the process being examined is receiving from processes that precede it in a FWC.

ToSIA generates information on sustainability impacts by calculating values of environmental, economic, and social sustainability indicators for production processes along the FWC. In ToSIA, the calculation of sustainability indicator values is linked to the material flow through the processes where the sustainability indicator results for a process are calculated by multiplying the input material flow of the process with efficiency parameters for each of the selected indicators.

In ToSIA prototype 2, the focus of programming work has been on implementing a working calculation engine. In prototype 2 a simple graphical user interface was created to simplify the generation of results. The implementation of more advanced functionalities and the development of an appropriate Graphical User Interface (GUI) will be taken up next. In ToSIA prototype 2, more information is provided to the user about selected demonstration results of calculations. The result presentation has been improved as well.

Application of ToSIA for Single FWC analysis

Single FWC analyses are the first applications of ToSIA in the EFORWOOD project and therefore they serve to test the prototype and to demonstrate the use of the model.

The aim was to represent the production processes in different parts of the Forestry-Wood Chain with comparable amount of detail. Three Single FWC applications have been developed using different perspectives of the Forestry-Wood Chain which have consequences for the definition of system boundaries for the analysis:

(i) a forest-defined FWC analysis is looking at the FWC from the forest resource perspective. This means that forest resources are regionally defined, but industrial processing and consumption of the products may also take place outside of the region where the forest resource is located. Example in EFORWOOD: **Forest-defined pine chain in Scandinavia for furniture and bio-energy**

(ii) a product defined FWC analysis is taking a different perspective with the starting point of the consumption of wood products in a specific region, whereas the industrial processing and forest resources may also be situated outside of the region. Example in EFORWOOD: **A product-defined fine paper/newspaper chain including recycling**

(iii) the third application of Single FWC analysis applies a regionally-defined perspective. This means that all the FWC processes occur within the study region. Example in EFORWOOD: **A regional-defined spruce chain in Baden Württemberg**

Reliable ToSIA outputs require reliable and complete input data. Therefore, data quality control represents an important part of the data gathering task in EFORWOOD. The data is introduced into the database from various sources (statistics, research data, modelling outputs etc.) with the help of the EFORWOOD database client. Numerous data collectors are involved in the project and it constitutes a challenge to ensure that assumptions and calculation routines are consistent throughout the chains. Currently, tools (routines) are being developed to check automatically inconsistencies in the reported data and also in the output data.

Using the data from the single chains three verification tests for ToSIA calculations were conducted. Tests were carried out by taking a sample of processes for which the calculations were performed.

The single chain calculations were initialised by fixing the amount of material flowing within the chain to comparable amounts. This was done for two test chains, the forest-defined pine chain in Scandinavia and the regional-defined spruce chain in Baden Württemberg. For the third chain, product-defined fine paper/newspaper chain including recycling, the ToSIA calculations were postponed to the phase of Case studies. This document presents a review of the results of two single chains, the forest-defined pine chain in Scandinavia and the regional-defined spruce chain in Baden Württemberg.

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1 Introduction

The objective of the EFORWOOD project is to develop a decision support tool for Sustainability impact assessment of the European Forestry Wood Chain (FWC). ToSIA (Tool for Sustainability Impact Assessment) will be the predominant product of EFORWOOD, integrating major outputs from the project-modules 2-5, which are dealing with Forest resources management (M2), Forest to industry interactions (M3), Processing and manufacturing (M4), and Industry to consumer interactions (M5).

ToSIA will allow various end-users, such as, national and international policy makers, researchers and the forest-based industry, to analyse sustainability impacts of changes due to deliberate actions (e.g. in policies or business activities) or due to external forces (e.g. climate change, global markets). More specific examples of these deliberate actions and external forces were reported in the deliverable 1.2.6.

ToSIA will be developed in EFORWOOD for sustainability impact assessments at three different scales:

1) **Single FWC** applications
2) FWC analysis in **Case Studies** with regional focus
3) **European FWC** analysis

The ToSIA modelling framework was described in the earlier Deliverable report D1.4.3. The data required for ToSIA are stored in the EFORWOOD database, which also contains the predefined chain topologies that are studied in the project. Linked to the database is the EFORWOOD Database Client that allows EFORWOOD partners to enter data and design chains. More information about the EFORWOOD database and the Database Client can be found in deliverable D1.2.5 and the Manual of the Database Client. Data quality issues within the EFORWOOD database are addressed in the deliverable 1.2.6 and they will also have an important role in the coming deliverable of the project.

The purpose of this deliverable report is to document the progress in ToSIA development since the release of D1.4.3 in February 2007. The application of the second ToSIA prototype to calculate sustainability indicators of Single FWCs is presented. The Single FWCs used in the EFORWOOD project are described and using examples from these chains, the procedure of calculating indicator values for the FWCs is explained. Initial results are presented regarding the calculated sustainability indicators. Attached to this report is the second ToSIA prototype. A compendium of commonly used terms and definitions is documented in the Annex 3.

2 Description of the ToSIA approach to Sustainability Impact Assessment of FWCs

The SIA of the forest-based sector in EFORWOOD builds on the conceptual representation of FWCs as chains of value-adding production processes (Päivinen & Lindner 2005). In Figure 1 the chain of production processes (shaded boxes) connected by an arrow line represents one simple FWC starting with forest resource management and ending with the end-of-life of a wood product. The basic concept of the representation of the FWC in ToSIA includes (i) the basic chain structure, and (ii) the wood flows through the chain of production processes. Sustainability impacts are measured in terms of environmental, economic and social indicators which are linked to the production processes of the FWC.

EFORWOOD is focusing on the assessment of sustainability impacts by comparing alternative FWCs in terms of their sustainability impact indicator performance.

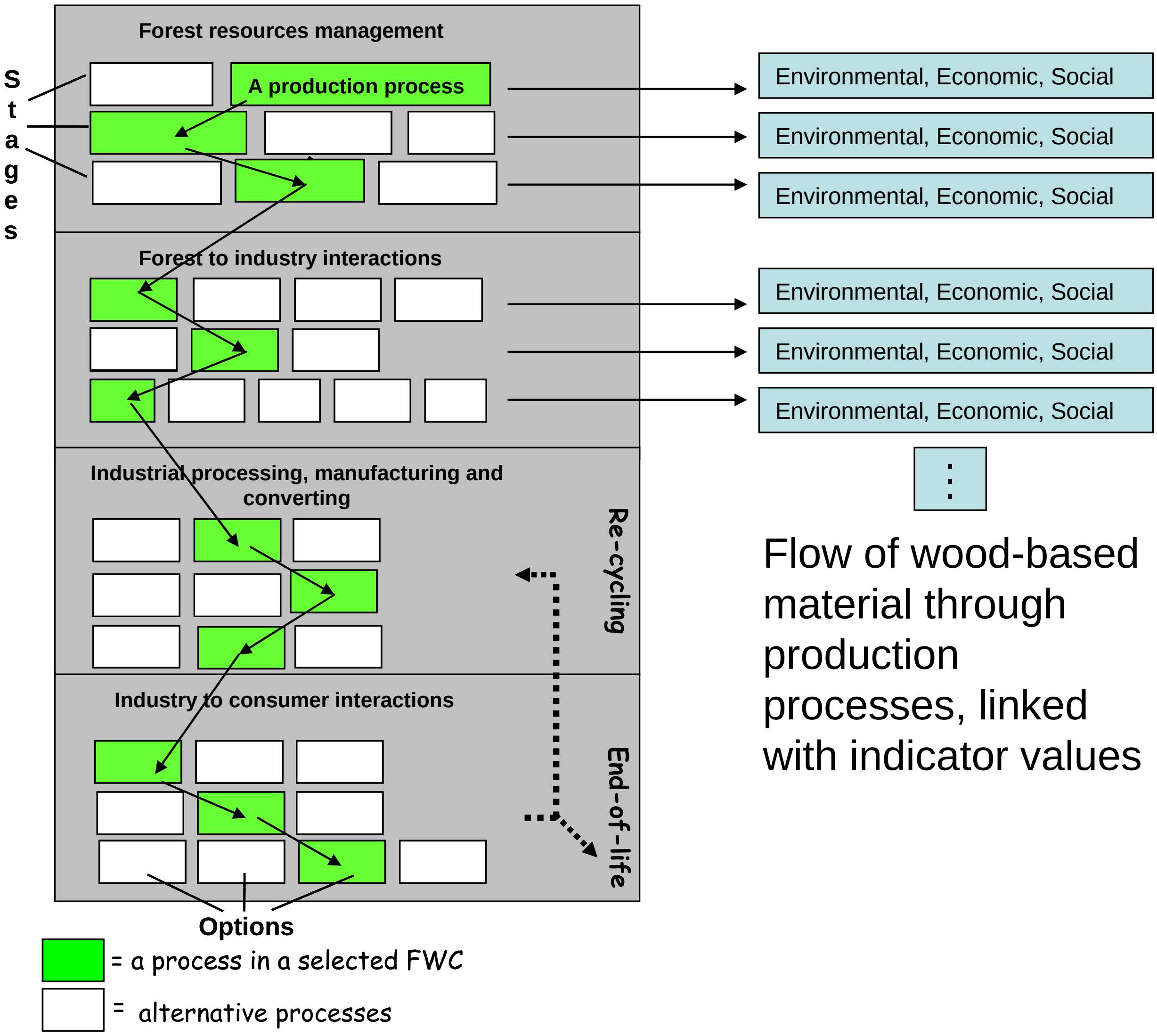

Figure 1. This is the methodological framework to assess the sustainability impacts of FWCs. The shaded boxes represent processes in one FWC. Each process is linked with a set of environmental, economic and social indicators.

A crucial concept of ToSIA is that all processes in different stages of the chain are calculated as they were occuring simultaneously because the impact assessment is calculated for the whole FWC for one specific year. The dynamic evolution of forests over time is excluded in the assessment of the baseline year 2005. In the case of Forest resource management (M2), it has some specific consequences that need to be considered in the indicator data collection (for more details on the time perspective used in ToSIA and consequences in M2 calculation refer to annex 1).

2.1 Defining chain structure

The FWC is understood in ToSIA as a dynamic structure linking production processes with input and output products. This structure is dynamic due to the fact that it can be altered in shape (i.e. the arrangement and amount of processes) while still using the same static information on processes and products.

Clear system boundaries have to be defined for each FWC. The specification of the FWC gives information about the number of processes that form a chain, the products that are included in the chain and the time period the data are valid for. The spatial boundary describes the geographical area the FWC or a process is representing. Moreover, each process needs to relate to a specified technology. The basic components needed to build up the different FWCs are:

a) Process (in a FWC)

The most important element of a FWC is a process. Transformation of energy and materials takes place in a process. In a process wood material will change its appearance and/or move to another location. Every process requires inputs and produces outputs. Inputs for each process in a chain are supplied by outputs of previous processes (Figure 2). Therefore in case of the FWC we call inputs and outputs simply products. Example of processes are - planting trees, stand treatments, harvesting, transport, sawing, pulping, papermaking, printing, etc...

b) Products

Products are the mass-based inputs and outputs of processes, such as spruce logs or finished wood furniture. The functional purpose of products is to link together processes to form chain structures (Figure 2). Processes can also receive input products from outside of the FWC system boundaries (e.g. non-wood material used in furniture manufacturing).

c) Product shares

For each process the input products to the process and their share (percentage of total input product), as well as the output products from the process and their specific share are specified (Figure 2).

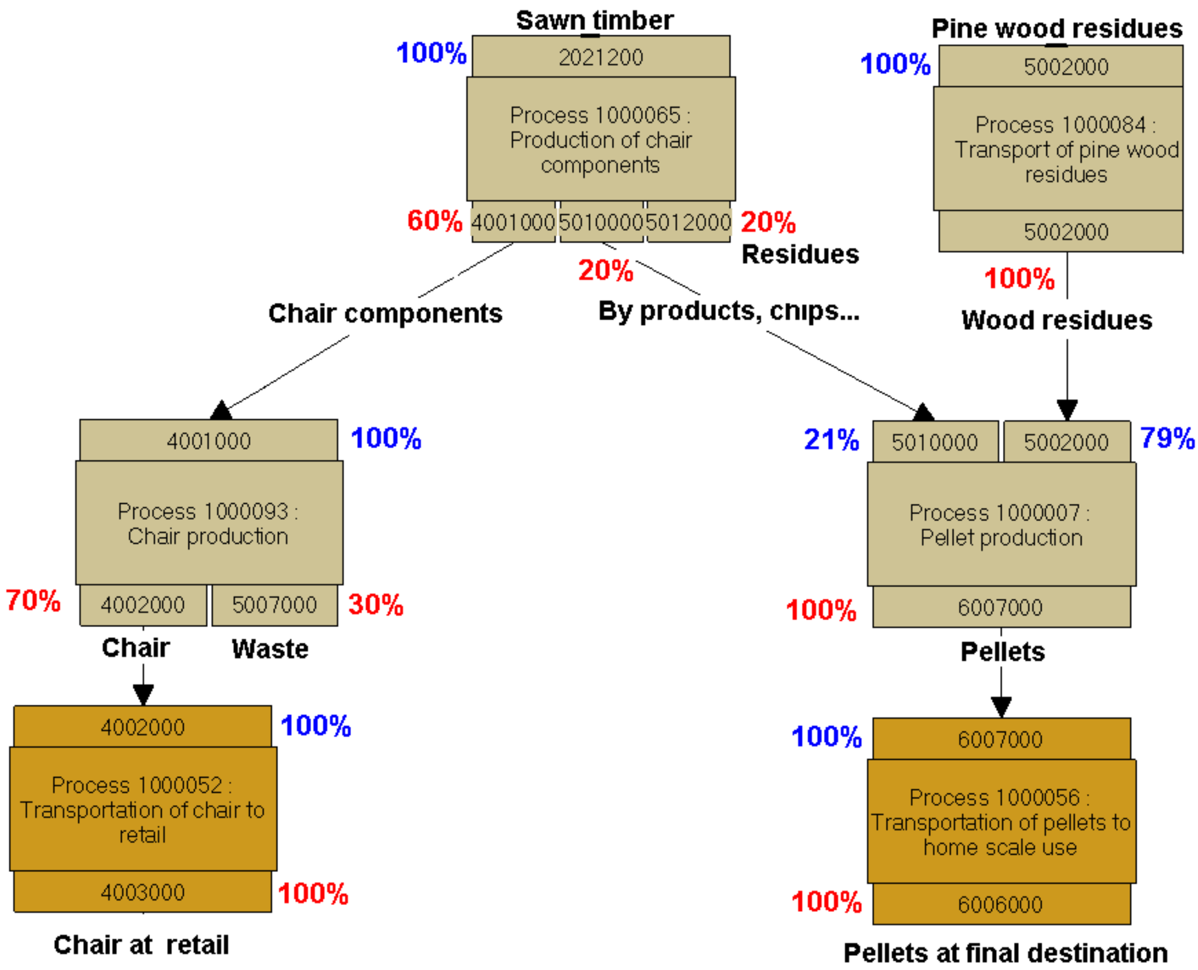

Figure 2. Some of the elements that form a forestry wood chain. Each process (name of the process inside the box) has at least one input product and at least one output product (names of the products outside the boxes); they are linking the different processes. The share of input products are shown in blue colour and the share of output products from each process are shown in red colour.

2.2 Tracking material flows along the FWC

A FWC is characterized by the material flow entering and leaving each process (Figure 2). The amount of material flowing through a process in a FWC as well as calculated process indicator values are calculated based on the amounts of material that the process being examined is receiving from processes that precede it in a FWC. The initialisation of the flow calculation gives a concrete amount of harvested wood biomass to be used as the basis for deriving all other material flows in the whole FWC being assessed. Currently it takes place at the boundary between the forest resource management (M2) and forest to industry interactions (M3). The consecutive calculation of material flows along the FWC is using the information of product output shares relative to the input flow of each process (Figure 2), which is also stored in the static information about production processes in the EFORWOOD database. The way that the calculation of flows takes place is explained in more detail in deliverable D1.4.3.

2.3 Linking sustainability indicators to processes

ToSIA provides information on sustainability impacts by calculating environmental, economic, and social sustainability indicators for production processes along the FWC (Figure 1). ToSIA utilizes indicators selected from the framework of sustainability indicators for the FWC, which are developed by WP1.1 together with all partners (cf. deliverable D1.1.1).

From the indicator framework (Deliverable D1.1.1) of the EFORWOOD project some indicators were selected for the first data collection round of the project and application in ToSIA. The development of the EFORWOOD indicators is an ongoing process and not all indicators have been ready for data collection on Single FWCs. It is planned to revise the indicator set taking into account the experience in data collection and sustainability assessment for Single FWCs to present a revised indicator framework for the data collection in EFORWOOD Case studies. Data collection protocols have been developed to give clear guidance for the indicators included in the data collection. The latest version of the data collection protocols is accessible via the EFORWOOD portal.

All indicators included in the indicator framework have defined measurement units (**Indicator measurement unit**) and the indicators are given for ToSIA per unit of material flow (the so called **reporting unit)**. In ToSIA, indicators are linked to the material input flow of the process in the selected FWC to compute the calculated process indicator value (see annex 1 for a detailed indicator value calculation).

Example
The production cost indicator (subclass labour cost) is calculated for the process transportation of pellets to home scale use:
- reporting unit of the material flow in the process = tons of pellets
- the measurement unit of the indicator = €
- the labour cost of transportation is 2,7 €/ton of pellets

Each process has only one reporting unit which is the same for all indicators (i.e. in our example above tons of pellets).

The internal **reference unit** used in ToSIA is one ha for Module 2, forest resource management, and one ton of C content in the wood or wood product for all other processes of the project modules 3-5. A **transformation factor** (different from conversion factors) is applied after the final process in M2 to convert M2 ha into tons of organic Carbon. This transformation factor considers all Carbon that is used as input to the first process of M3 (C in stem wood and C in residues).

As especially in M3-M5 the indicators may be reported with different reporting units (in the previous example ton of pellets), **conversion factors** are required to convert the reporting units in the database to the reference unit “tons of C content” and vice versa. For each individual product occuring in the FWC a conversion factor is required. See Annex 4 for the documentation of conversion factors of the Single FWCs.

The indicator values per material flow (e.g. labour cost of the transport of pellets is 2.7 €/ton of pellets) are submitted to the EFORWOOD database from project modules 2-5. In most cases they are derived from available statistical data sources or they are generated from outputs of process-specific models and data available to M2-M5. Expert judgements are also used, particularly with qualitative indicators. In any case, the indicator values reflect the best available knowledge about the sustainability of the processes included in the selected FWCs.

2.4 Calculating sustainability indicator values of the FWC

After calculating the material flow along the FWCs, each process is associated to a group of indicators expressed with an **indicator value per material flow** (material flow unit here is expressed in reporting unit). In ToSIA, sustainability indicators are linked to the material input flow of the process, therefore, the absolute sustainability indicator values for a process that are called **calculated process indicator values** are computed multiplying the input material flow of the process (converted from the internally used reference unit (ha or tons of Carbon) to the appropriate reporting unit) with each of the process' indicators values per material flows. In order to transform the input material flow to the appropriate reporting unit of a process (m^3, or ton of product, etc…) conversion factors are used. In this context, conversion factors for products, which are going in and coming out of production processes are necessary information for ToSIA calculation.

After defining the calculated process indicator values with the total material flows for each process, ToSIA aggregates them along the FWC to determine the so-called calculated FWC indicator values. For example, ToSIA can calculate the total employment within the studied FWC. For most of the indicators, the aggregation can be done simply by summing the indicator values of individual processes together. However, some indicators may be by nature such that summation is not reasonable. For example, those indicators that represent relative shares, like Occupational accidents, should be averaged instead of summed. In this current version of ToSIA, the aggregation method was individually specified for each single indicator. In the future there is a need for experts to define the aggregation methods for each indicator and the flexibility for choosing those methods in the software.

In the sustainability impact assessment it is possible for some indicator subclasses to be aggregated together. For example, total employment is the sum of the subclasses employment male and employment female. As long as the units of the indicators are compatible, the aggregation of the indicators is straightforward.

Aggregation of the indicator values in this prototype of ToSIA are done by ToSIA for selected indicators. In addition to that the user can do the aggregation outside ToSIA based on process level results in result files. For the final ToSIA version the aggregation is planned to be one of the features that the user can define within the graphical user interface.

2.5 Technical implementation of the ToSIA prototype 2

In this section only a brief introduction to the ToSIA prototype 2 is given. For a more comprehensive description, we refer to the Annex 1 and 2.

In ToSIA prototype 2, the focus of work has been on implementing a working calculation engine. The implementation of a proper graphical user interface and more advanced functionality in general will follow next. In prototype 2, a simple graphical user interface was created to aid in the production of results. For the calculations ToSIA receives its input data from the EFORWOOD database. The flow calculation in ToSIA prototype 2 is similar to the first prototype. Since the prototype 1, more information is now available from the EFORWOOD database. This has enabled refining and extending previously existing ToSIA functionality. More information is now given to the user about the results of the flow calculation and the result presentation has been improved as well. The calculation of the input material flow includes now also dealing with recycling loops in predefined Single FWCs (excluding the paper/newspaper chain).

The basic steps followed by ToSIA to make the calculation of the sustainability indicators are shown in Textbox 1.

Textbox 1. Basic steps followed by ToSIA prototype 2 to make sustainability calculation.

The ToSIA sustainability calculation proceeds as follows:

1. Data is read into ToSIA prototype 2 from the EFORWOOD database via two xml-files produced by the database client. First the static information of the available processes is loaded. This info is grouped into modules and contains the stage inside the module and possibly some metadata characterizing the processes.
2. The second xml-file containing the definition of the structures of the different FWCs[a] is read in and the chain-structures for ToSIA are built based on this information. For each process included in the chain the static process information previously read in is referred to.
3. Once the structures of the FWCs are established, the material flows along the FWC are calculated using a single initialisation flow at the M2/M3 boundary. The material flows, which stream through subsequent processes are calculated based on product shares stored with the static process information.
4. Calculated process indicator values are computed for all processes by multiplying the material flow through the process with the indicator values per material flow stored in the EFORWOOD database. Internally a conversion of the material flow unit is performed so that it matches the unit used to report the indicators.
5. Calculated process indicator values are aggregated along the chain with arithmetic operations. Aggregation method (i.e. summing or averaging) differ between indicator types.

[a] Currently, the xml-file contains the definitions of all chains from the database and they are all built in ToSIA each time the xml-file is read. In future, more efficient ways to transfer and handle the chain structure information will be studied.

The ToSIA prototype 2 is now implemented to handle the specified Single chains. The main ToSIA will be implemented to also handle the Case Studies and European FWC. The purpose of the prototyping phase has been to refine the specification of the model and the data to be analysed. The model has evolved and changed along the timeline of ToSIA development, and we have now reached a phase where the fundamental requirements have become clear enough that it is sensible enough to actually design software. The final version of ToSIA in this project will be based on the prototyping work and implemented using the OpenMI framework (For further information, see www.openmi.org). OpenMI gives to the project a significant amount of ready solutions for integration of models and some aid in presenting model results. Solutions implemented using standardized methods tend to have better maintainability than completely customized solutions.

3 Application of ToSIA for Single FWC analysis

3.1 Specification of Single FWCs

The FWC is considered in ToSIA as a dynamic structure linking processes and describing the material flow entering and leaving each process. The three Single FWCs that will be used within the EFORWOOD project are presented here as well as all the components needed for setting up the single chains (processes, products, product shares and conversion factors).

a) Single FWCs

Single FWC analyses are the first applications of ToSIA in the EFORWOOD project and therefore they serve to test the prototype and to demonstrate the use of the model. In cooperation between ToSIA developers and experts in Modules 1-5 the chain specifications have been elaborated in an iterative process. The aim was to represent the production processes in different parts of the Forestry-Wood Chain at similar detail. Three Single FWC applications have been developed using different perspectives of the Forestry-Wood Chain which have consequences for the definition of system boundaries for the analysis:

(i) a forest-defined FWC analysis is looking at the FWC from the forest resource perspective. This means that forest resources are regionally defined, but industrial processing and consumption of the products may also take place outside of the region where the forest resource is located. Example in EFORWOOD: **Forest-defined pine chain in Scandinavia for furniture and bio-energy**

(ii) a product defined FWC analysis is taking a different perspective with the starting point of the consumption of wood products in a specific region, whereas the industrial processing and forest resources may also be situated outside of the region. Example in EFORWOOD: **A product-defined fine paper/newspaper chain including recycling**

(iii) the third application of Single FWC analysis applies a regionally-defined perspective. This means that all the FWC processes occur within the study region. Example in EFORWOOD: **A regional-defined spruce chain in Baden Württemberg**

3.1.1 Forest-defined pine chain in Scandinavia for furniture and bio-energy

The forest-defined pine chain is based on the wood material flows emanated from a Scots Pine management system in Northern Sweden. Two products are distinguished in the FWC: a chair, representing wooden furniture, and pellets as a bio-energy product. Typical production processes for a wooden furniture value chain have been specified and the wood residues that accrue as by-products of saw milling and furniture manufacturing are utilized to produce pellets for use in a private household. The processes involve the pulp wood collected from the same forests until the gate of the pulp mill. The chain involves altogether 26 processes (Table 2).

Table 2. Processes of a forest-defined pine chain in Scandinavia for furniture and bio-energy production. Process names are taken from the data base client as they are inserted there.

Module	Process name
M2 - Forest resources management	Scarification and planting of pine
	Development of planted pine stand in young phase with 1 pre-commercial thinning[a]
	Development of planted pine stand in medium phase
	Development of planted pine stand in adult phase
M3 - Forest to industry interaction	Pre-commercial thinning of planted pine stand in young phase
	Felling with large harvester
	Clear cut with large single-grip harvester
	Transport by 60t truck with crane acc to assortment[b]
	Forwarding of pine after thinning
	Forwarding of pine after final felling
	Final measuring and sorting of pine logs according to quality at sawmill
	Final measuring and sorting acc. to quality at pulpmill
	Final measuring and sorting acc. to quality at sawmill
M4 - Processing and manufacturing	Pine timber conversion at saw mil
	Transport of sawn pine timber
	Production of chair components
	Transport of pine wood residue
	Chair production
	Pellet production
M5 - Industry to consumer interactions	Transportation of chair to retail
	Transportation of chair to customer
	Using the chair
	Transport of chair to end of life
	Incineration with energy recovery and ash disposal
	Transportation of pellets to home scale use

[a] This process belonging to M2 describe the management regime to apply but the actual pre-commercial thinning takes place in M3.
[b] Different products are transported separately.

3.1.2 A regional-defined spruce chain in Baden Württemberg

A regional-defined spruce chain in Baden-Württemberg consists of spruce management systems that produce timber from thinnings for the use in construction of a timber-frame house. This chain includes two alternative management practises based on natural regeneration and planting. The alternative chains were built separately to allow a simple scenario comparison employing the evaluation prototypes developed in WP 1.5. Whereas the chain alternatives use the same processes for processing and manufacturing (M4) and for the industry to consumer interaction (M5), they differ in the resource management and the harvesting and transport technology. For example, in planted stands the cuttings are performed with large harvesters including pre-sorting with a final product being short, whereas in stands with natural regeneration cuttings are done manually, and the whole trees are transported to the road using skidders, and trees are cut and sorted at forest road. Wood for pulp production is exported out of the chain and log wood is used for panel production. Table 3 shows the processes of these chains.

Table 3. Processes of regional-defined spruce chains (natural regeneration and planting) in Baden Württemberg. Process names are taken from the data base client as they are inserted there.

Module	Natural regeneration Process name	Planting Process name
M2 - Forest resources management	Regeneration with natural regeneration and weeding	Regeneration with planting and weeding
	Development of naturally regenerated spruce stand in young phase with 1 pre-commercial thinning	Development of planted spruce stand in young phase with 2 pre-commercial thinnings
	Development of naturally regenerated spruce stand in medium phase	Development of planted spruce stand in medium phase
	Development of naturally regenerated spruce stand in adult phase	Mature stand development
M3 - Forest to industry interaction	Pre-commercial thinning operations	Pre-commercial thinning operations
	1.-2. thinning: motor-manual Cutting - debranching measuring and sorting acc. to quality	1.-2. thinning: full-mechanized cutting with medium harvester - debranching - evtl. pre-sorting
	3.-6. thinning: motor-manual Cutting - debranching measuring and sorting acc. to quality	3.-6. thinning: full-mechanized cutting with large harvester - debranching - evtl. pre-sorting
	Skidding with double-winch wheel skidder[a]	Forwarding with medium forwarder after 1st. Thinning
		Forwarding with medium forwarder after 2nd. Thinning
	Transport by truck for long timber with crane	Transport by truck for short timber with crane
	Final measuring and Sorting - long timber	Final measuring and sorting - short
M4 - Processing and manufacturing	Saw milling	
	Transport of spruce wood residues from saw milling	
	Panel production	

	Assembly of external wall panels
M5 - Industry to consumer interactions	Transport of external wall panels to building site House construction with timber frame Use of building Demolition of building Transport of demolished parts of building

[a] Different wood assortments in their separate processes.

3.1.3 A product-defined fine paper/newspaper chain including recycling

The product-defined FWC includes two paper products: the first product is fine paper for office use, which is produced from virgin fibres including eucalyptus pulp from Portugal and kraft pulp from Northern Sweden. After office use, the paper is recycled and the fibres are reused in the second paper product – a newspaper. In this Single FWC the consumption of the paper products takes place on the Iberian Peninsula, whereas the original fibre is partly imported from outside the region. Table 4 shows the processes of this chain.

Table 4. Processes of a product-defined fine paper/newspaper chain including recycling.

Module	Process name
M2 - Forest resources management	Application of fertilizers and thinning of eucalyptus saplings on second and third coppice rotation Development of coppiced eucalyptus stand in young phase with harrowing and fertilization Development of planted pine stand in young phase with 1 pre-commercial thinning Development of planted eucalyptus in young phase with 3 weed controls and 2 fertilizations Development of coppiced eucalyptus stand in medium phase with harrowing Development of planted pine stand in medium phase Development of planted eucalyptus stand in medium phase Development of planted pine stand in adult phase
M3 - Forest to industry interaction	Clear cut with large single-grip harvester (pine) Harvesting of planted eucalyptus with medium single-grip harvester Felling with large harvester (pine) Harvesting of coppice eucalyptus with small single-grip harvester Pre-commercial thinning of 6-7 shoots per stool on second and third rotation (eucalyptus) Forwarding of pine after thinning Forwarding of pine after final felling Forwarding by medium forwarder (12 tons) (eucalyptus)a Transport by truck with crane (eucalyptus)[a] Final measuring, grading and sorting(eucalyptus) [a] Transport by 60t truck with crane acc to assortment (pine)[b] Final measuring and sorting acc. to quality at pulpmill (pine) [b]
M4 - Processing and manufacturing	Market kraft pulp mill in Sweden (pine) Pulp transport to Portugal (pine) Integrated pulp and paper production (pine, eucalyptus) Pulping (de-inking) and newsprint production from recovered fibres (pine, eucalyptus)
M5 - Industry to consumer interactions	Transportation of newsprint ES Distribution of newspaper to subscribers Whole sale distribution of fine paper ES

Transportation of recovered paper
Newspaper printing – Cold-set web offset ES
Office printing laser b/w
Information – use
Information/entertainment - use of newspaper ES
Transport of used paper in mixed waste
Separate collection
Landfill of used paper
Incineration of waste paper

[a] In the case of eucalyptus forwarding and transport of wood is the same process regardless if the product is coming from thinnings or final cuttings.
[b] In Scots pine, transport and final measuring are considered different processes for the different assortments

3.2 *Checking data consistency before calculations*

Reliable ToSIA outputs require reliable and complete input data. Therefore, data quality control represents an important part of the data gathering task in EFORWOOD (Figure 3). The data is introduced into the database from various sources (statistics, research data, modelling outputs etc.) with the help of the EFORWOOD database client. Numerous data collectors are involved in the project and that constitutes a challenge to ensure that assumptions and calculation routines are always consistent with each other.

One important precondition for running ToSIA is the complete and consistent set of the conversion factors reported in the database.

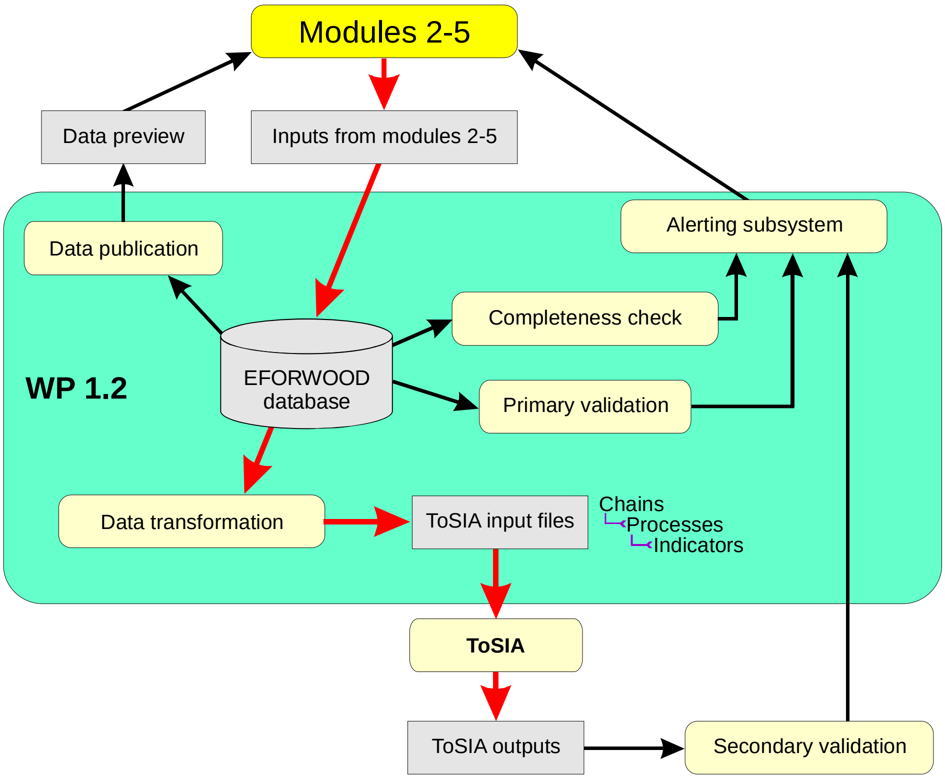

Figure 3. The EFORWOOD database collects the information from the project modules 2-5 and provides the necessary input data to run ToSIA. Data quality checks are done in several steps to

secure best possible output quality of the ToSIA results. The first data check is performed when data are submitted to the database. Both completeness of the data and individual values are checked.

Currently, tools (routines) are being developed to check automatically inconsistencies in the reported data. These routines will allow the user to detect mistakes or errors in the ToSIA database before the tool is calculating indicator. There are different potential problems that can occur in a database and which should be checked to ensure the validity of the results obtained when running ToSIA. First of all, gaps in data needed for the calculations need to be identified and filled. Also the consistency of the indicator units has been noticed to be a matter that should be checked. One important check concerns the share of product outputs from a process. The product output shares refer to the percentage of the total output material flow from the process corresponding to each of the output products. The sum of shares of the product outputs from one process can not be more than 100% of the input material flow to the process. Smaller numbers are possible if some process waste is unaccounted for (e.g. dust emissions). A more detailed presentation of the analysis of data quality can be found in Deliverable Report D1.2.6.

3.3 Verification of calculation procedure

Technical verification of the calculation procedures within ToSIA was performed with a set of tests. Technically tests were carried out using a Single FWC (Scandinavian pine chain) data. The program uses always the same basic calculation, therefore, if a calculation in one chain for one indicator is correct, all other similar calculation for other processes and chains should be correct too.

In order to ensure that calculation procedure of ToSIA is technically correct, the following tests were conducted:

a) Test of the material flow calculations within the chain for all the modules

In the Single FWC analysis, the material flow calculations start with the initial amount of 1000 tons of carbon in the first process of M3 (final cutting). From this point, first the amount of area that should be cut is calculated with a transformation factor. The area calculated is assigned to all the M2 processes “upstream” assuming a normal forest with even distribution of age classes. The amounts that accrue during the development to a stand in adult phase are calculated by several time multipliers and conversion factors. The next step was to verify whether the flow amounts passing the M2-M3 boundary are distributed correctly from process to process along the FWC “downstream”. An important issue here was to check if the input and output flows of each process were correct including the shares of products. Another important issue when checking the material flow was the aggregations of more than one input flow were correct (several processes have at least two input flows.

b) Test of the correctness of ToSIA to read the information from the database necessary to calculate process level indicators and check the process indicator calculation procedure

First, the correctness of ToSIA to read the information stored in the EFORWOOD database was checked.

Second, the technical procedure to compute the calculated process indicator values was checked. For that, the conversion from input flows measured in tons of C into reporting unit was tested. In cases with two input flows also the aggregation of the converted values was checked.

c) Test of the aggregation calculations including reporting results.

All single results of a specific indicator in the four modules were aggregated manually and compared with the results of ToSIA.

3.4 Single chain analysis

Using the ToSIA prototype 2, the sustainability indicators were calculated for the forest-defined pine chain in Scandinavia and the regional-defined spruce chain in Baden Württemberg. For the third chain, product-defined fine paper/newspaper chain including recycling, the ToSIA calculations were postponed to the phase of Case studies later in the project, because of incomplete indicator information and the more difficult implementation of recycling loops in the ToSIA prototype. The recycling loops algorithms will now be implemented in the Open MI version of ToSIA, in which the calculation of such loops is easier to handle.

3.4.1 Forest-defined pine chain in Scandinavia for furniture and bio-energy

The Single FWC calculations were initialised by fixing the flow from M2 to M3 to be 1000 tons of carbon in the process 1000003 “clear cut with large single-grip harvester”. This initialisation thus fixed the amount of material flowing within the chain. Material flow in processes is presented in Table 5.

Table 5. Example from the forest-defined pine chain in Scandinavia including the processes names and the amount of flow from one process to another and the forest resource. The percentage near the product name means the share of this output product regarding the total output product for the same process; whenever there is not share near the product name means that there only exists one product for this process and therefore, the share would be 100%,

Module	Process name	Product name	Output flow or forest resource use
M2 - Forest resources management	Scarification and planting of pine	Regenerated site	60,96 ha
	Development of planted pine stand in young phase with 1 pre-commercial thinning	Young stand	142.23 ha
	Development of planted pine stand in medium phase	Medium aged stand	203.19 ha
	Development of planted pine stand in adult phase	Mature pine forest ready for clear felling	1320,73 ha
M3 - Forest to industry interaction	Felling with large harvester (Thinning)	17% Saw logs (incl. downgraded fuelwood) [a]	239 m^3

		60% Pulpwood: (incl. downgraded fuelwood) [a]	863,00 m^3
		23% Harvest residues left on site	315 m^3
		22% (explain)	
	Forwarding of pine after thinning	Sawlogs (fuelwood incl.) piled at the road side acc to size and quality([a, b])	239 m^3
	Clear cut with large single-grip harvester	46% Saw logs (incl. downgraded fuelwood)	2063 m^3
		33% Pulpwood: (incl. downgraded fuelwood)	1528 m^3
		21 % Harvest residues left on site	972 m^3
	Forwarding of pine after final felling	100% Sawlogs (fuelwood incl.) piled at the road side acc to size and quality (a, b,c)	2303 m^3
	Transport by 60t truck with crane	100% Timber (fuelwood incl.) transported to saw mill (a, b, c)	2156 tons of wood 2303 m^3
	Final measuring and sorting of pine logs according to quality at sawmill	95% Sawlogs transported to saw mill (b, c)	2152 m^3
		5% Fuel wood	4 m^3
M4 - Processing and manufacturing	Pine timber conversion at saw mil	35% wood residues ready for pellet production	691 m^3
		60% Sawn timber	1185 m^3
		5% Other pine wood residues	99 m^3
	Transport of sawn pine timber	Sawn timber ready for manufacturing	616,30 ton wood 1185 m^3
	Transport of pine wood residue	Wood residues ready for pellet production	71 ton C 99 m^3
	Production of chair components	60% Chair components	711 m^3
		20% By products, chips	237 m^3
		20 % Other residues	237 m^3
	Chair production	Chair	711 m^3 wood 369,7 tons chairs
	Pellet production	Pellets	928 m^3 of wood, 459.47 m^3 of pellets
M5 - Industry to consumer interactions	Transportation of chair to retail	Chair at retail	369,7 tons of chairs
	Transportation of chair to customer	Chair at final destination	369,7 tons of chairs
	Using the chair	Used chair	369,7 tons of chairs
	Transport of chair to end of life	Used chair at incinerator	369,7 tons of chairs
	Incineration with energy recovery and ash disposal	Energy (electricity and heat)	15,84MJ/m^3*711 m^3 wood= 11262 MJ
	Transportation of pellets to home scale use	Pellets at final destination	227,44/0,495=459,47 m^3 of pellets = 505 ton pellets
	Consumption, energy heat production	Energy (electricity and heat)	-

[a] Fuelwood is still included in this product and will be separated in the saw mill
[b] This process is used for the output of more than one process (the amount of product shown is the sum of all the input products)

[c] The amount of wood leaving the FWC as pulp wood is not taken into account. Only saw wood is presented

The data provided for the pine chain was classified by the experts providing the data depending on the quality and indicating if the indicators were available or not, and also if they were applicable for this forestry wood chain (FWC). To define the quality there are different concepts to take into account: i) completeness, ii) reliability, iii) free of error iv) source of the data. The quality of the reported values was mainly marked as high or medium (Figure 4). Relatively high number of non-reported quality figures comes mainly from the 0-values for which the users had not given any quality classification.

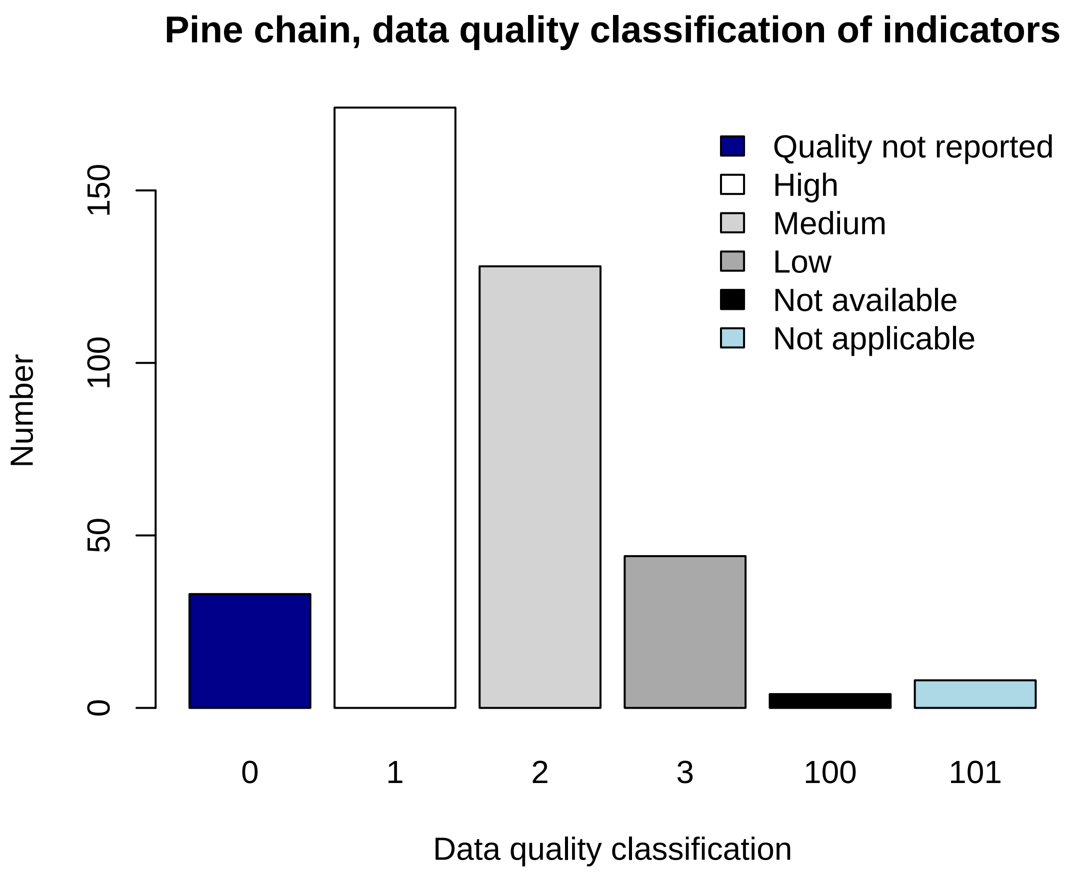

Figure 4. Indicator data quality classification given in the database for the indicators of the Scandinavian pine chain.

Indicator values per material flow are given for each process. The calculated process indicator values are then computed for single processes by multiplying the indicator values per material flow with the material flow. An example of the calculated process indicator values is given in Figure 6. It is important to note that in the current way of presenting results, the material flow from forest to the end-product gets smaller and smaller, because the system boundaries are currently following the physical structures of the built chains. Consequently, the relative contribution of M2 and M3 to overall sustainability is over-represented. See discussion for further explanation.

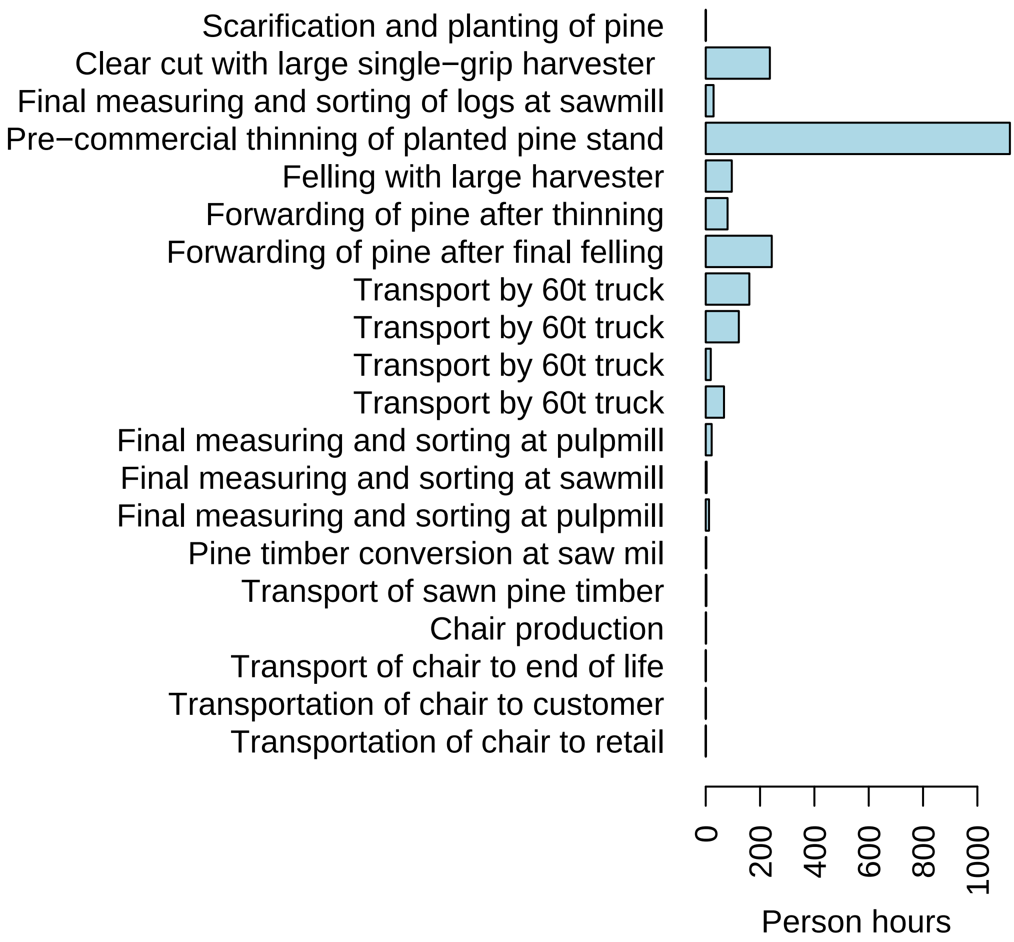

Figure 5. Indicator "Employment" (in person hours) by processes for the forest-defined pine chain.

Calculated process indicator values can be aggregated and shown by modules, Forest resources management (M2), Forest to industry interactions (M3), Processing and manufacturing (M4), and Industry to consumer interactions (M5). In Figure 6 the indicator Wages and Salaries is shown at the module level.

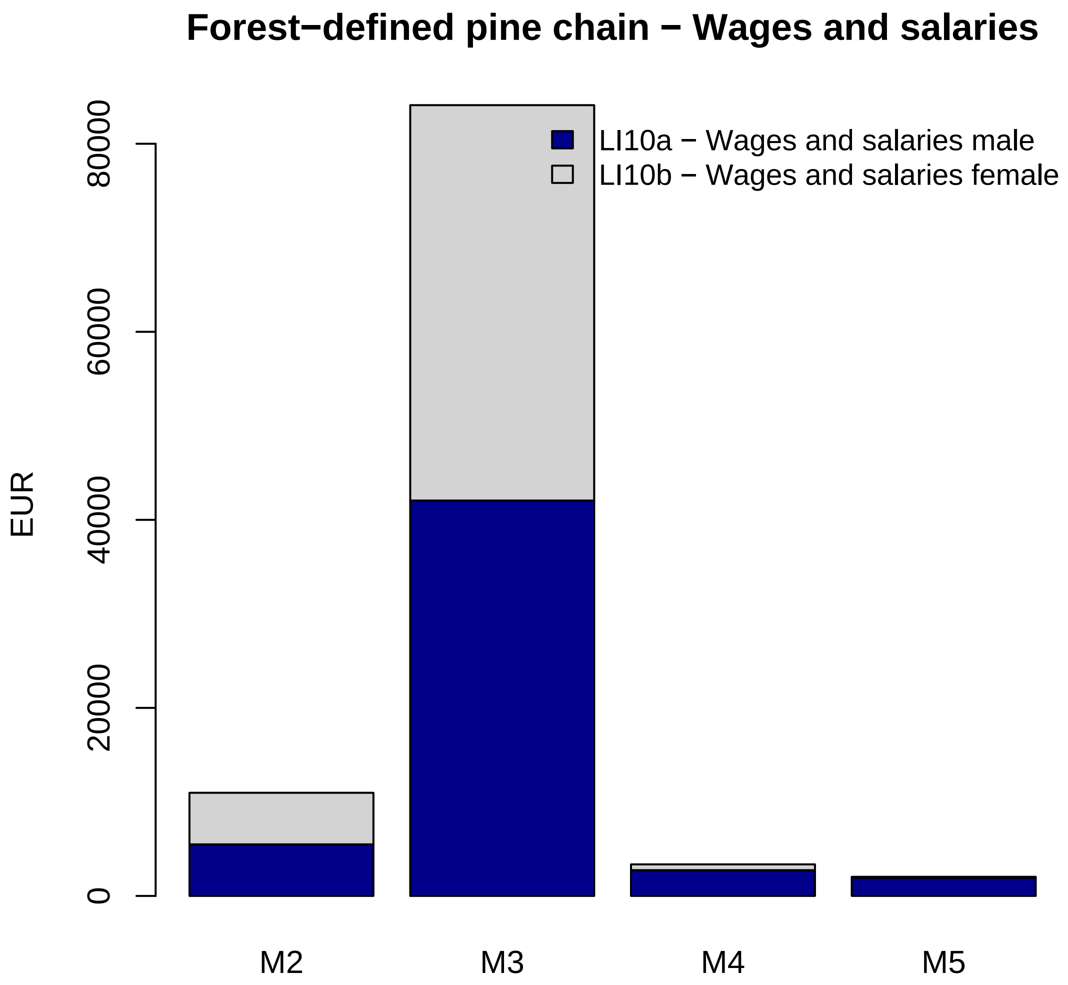

Figure 6. Indicator “Wages and salaries” of the Forest-defined pine chain shown by modules.

The highest level of aggregation is to show one indicator for the whole chain (calculated FWC indicator value). The reliability of these calculated FWC indicator values depends on both the reliability of the single values as well as on the completeness of the data for the whole chain. Due to the lack of data or incorrectness in some of the reported indicator data, we selected only six indicators for further analyses in this report. The rest of the indicators will be used and analysed later. In Table 6 the results of the six selected aggregated indicators of the Forest-defined pine chain are presented with the number of single indicators behind the values reported for different processes. The six indicators represent the three pillars of sustainability: Total production costs and Total resource use are economic indicators, Employment and Wages & salaries represent social indicators, whereas Energy use and Total greenhouse gas emissions belong to the environmental indicators. Each of these indicators was aggregated along the FWC by summing up.

Table 6. Calculated FWC indicator value (aggregated values over the whole chain) for six selected indicators for the forest-defined pine chain in Scandinavia for furniture and bio-energy.

Aggregated indicator	Indicators included in the aggregated indicator	Value over chain	Unit	Number of reported values (<>0) behind the aggregated value
Total production costs	LI02a - Production cost - raw materials from FWC LI02b - Production cost - raw materials from outside FWC LI02c - Production cost - labour costs LI02d - Production cost - energy costs LI02e - Other productive costs LI02f - Non-productive costs	308	1000 EUR	2+1+16+11+12+10 = 52
Total wages and salaries	LI10a - Wages and salaries male LI10b - Wages and salaries female	100	1000 EUR	24+23 = 47
Total employment	LI10a - Wages and salaries male LI10b - Wages and salaries female	2443	person hour	23+22 = 45
Total GHG emissions	LI14.1 - Greenhouse gas emissions per process	18	1000 tons of CO_2 eq.	26
Total energy use	LI13.2.a - Energy use (renewable) LI13.2.b - Energy use (non-renewable) LI13.2.c - Energy use (electricity from the grid)	5.1	TJ	16+21+16 = 53
Total resource use[a]	Calculated by ToSIA	6.1	1000 m^3	

[a] Calculated here based on material flow over the M2/M3 boundary.

3.4.2 A regional-defined spruce chain in Baden Württemberg

The general level of the data quality reported in the database for the spruce chain was lower than for Scandinavian pine chain (Figure 7). There were more missing quality notations and also the reported quality figures were not as high as for the pine chain.

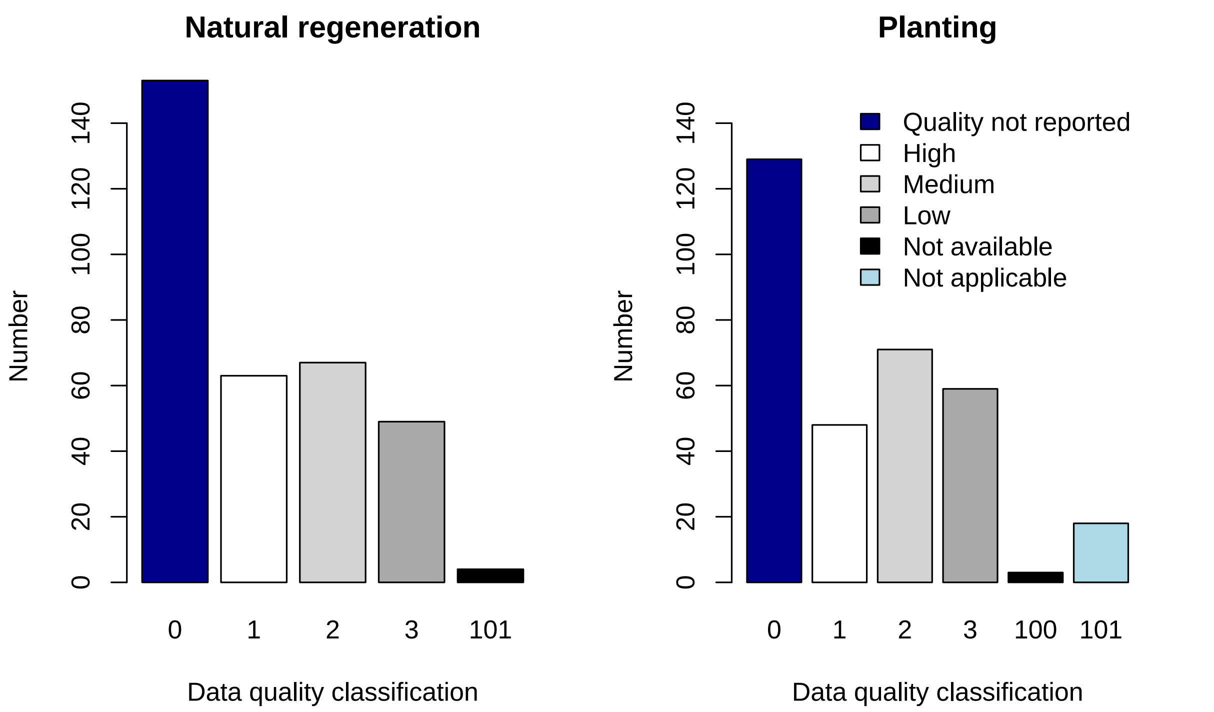

Figure 7. Indicator data quality classification given in the database for the indicators of the Regional-defined spruce chain in Baden Württemberg. Figures are given separately for natural regeneration and planting chains.

An example of the calculated FWC indicator value is in Figure 8.

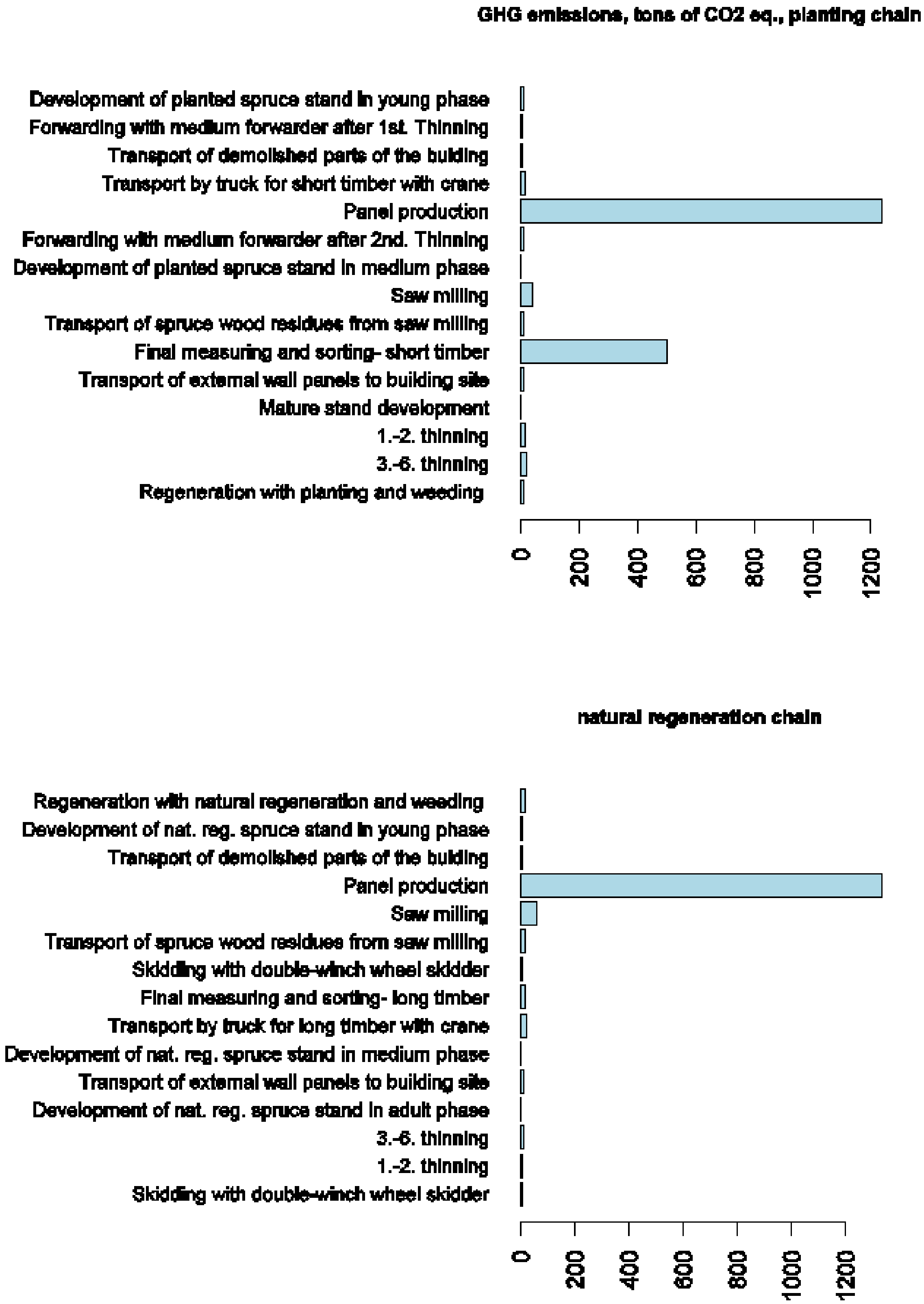

Figure 8. Indicator “Greenhouse gas emissions” of Regional-defined spruce chain at the process level. (top: chain with planting; bottom: chain with natural regeneration).

In Figure 9, Wages and salaries of the Regional-defined spruce chain are given by Modules. As these chains are identical in M4 and in M5, the differences between the indicator values in these modules are caused by small differences in material flow in the chains.

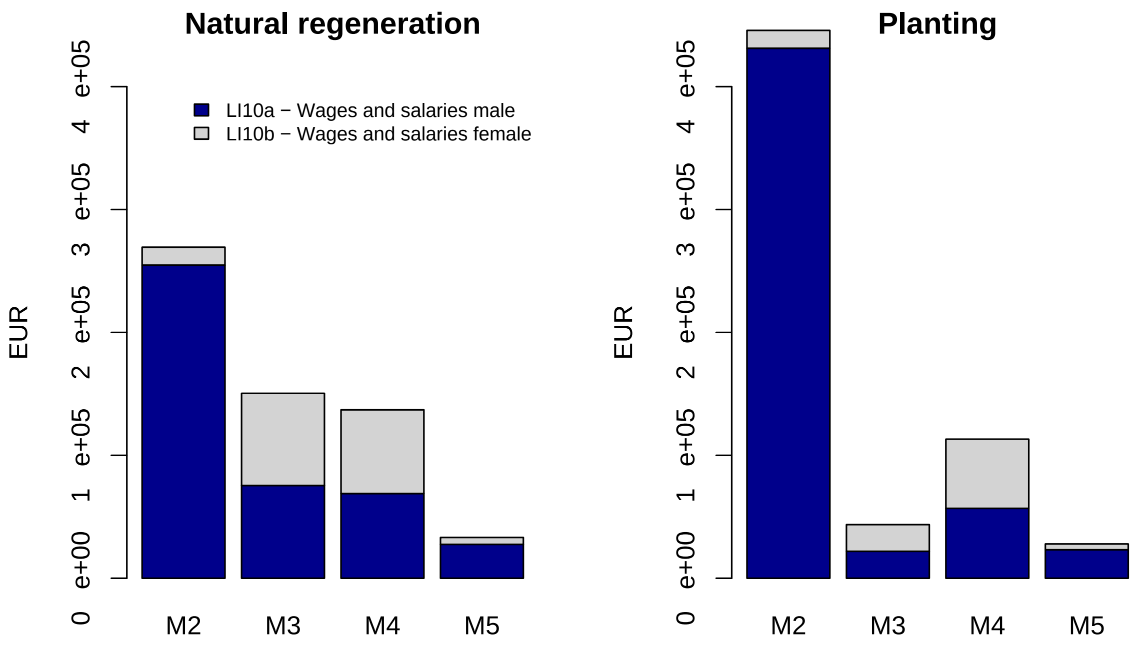

Figure 9. Wages and salaries of the regional-defined spruce chains shown by modules.

In Table 7 the results of the six selected aggregated indicators of the regional-defined spruce chain in Baden Württemberg are presented with the number of single indicators behind the values reported for different processes.

Table 7. Aggregated values for six selected indicators over the whole chain, regional-defined spruce chain in Baden Württemberg.

Aggregated indicator		**Value over chain – Natural regeneration**	**Value over chain - Planting**	**Unit**
Total production costs	LI02a - Production cost - raw materials from FWC	773	895	1000 EUR
	LI02b - Production cost - raw materials from outside FWC			
	LI02c - Production cost - labour costs			
	LI02d - Production cost - energy costs			
	LI02e - Other productive costs			
	LI02f - Non-productive costs			
Total wages and salaries	LI10a - Wages and salaries male	590	630	1000 EUR

	LI10b - Wages and salaries female			
Total employment		29	49	person year
Total GHG emissions	LI14.1 - Greenhouse gas emissions per process	1.5	1.9	1000 tons of CO_2 eq.
Total energy use	LI13.2.a - Energy use (renewable)	29	24	PJ
	LI13.2.b - Energy use (non-renewable)			
	LI13.2.c - Energy use (electricity from the grid)			
Total resource use[a]	Calculated by ToSIA	7.52	7.54	1000 m^3

[a] Calculated here based on material flow over the M2/M3 boundary.

4 Discussion

WP 1.4 develops the ToSIA tool framework, tests the tool and calculates sustainability indicators for current and future alternative FWCs at regional and European levels. Objectives of the WP are to identify relevant processes in the FWC together with Modules 2-5, to define the system boundaries between the main stages of the FWC, as well as between the FWC and the outside world, to develop ToSIA model variants for different applications in EFORWOOD, to test ToSIA using simple test chains, to develop and explore alternative FWCs based on commonly agreed scenarios and to simulate the effects of these scenarios on indicators of current and alternative FWCs at the regional and continental scale taking into account internal and external drivers.

While prototype 1 relied on the input of material flow data along the chain, these flows are now calculated from the tool using only the initial flow information at the M2/M3 boundary. In addition, ToSIA prototype 2 gives more information to the user about the results of flow calculation and presents it in a more collected way than the previous version. In ToSIA prototype 2, an attempt was made to implement the calculation of flows in loop-structures. This lead to the discovery of new issues that need to be resolved before loop calculation can be successfully implemented in such a way that all reasonable loop structures can be generically handled.

Single FWCs described above in Section 3 were created to demonstrate and test the current ToSIA prototype. Tests showed that ToSIA functions meaningfully and that the approach is reasonable. The Single FWC also gave important experiences with regard to data collection and handling and revealed several points in data collections that require special attention in the following data collection attempts. Examples of the lessons learnt and suggestions for the future work are collected in Table 8.

Table 8. Experiences from the data collection for the Single FWCs and suggestions for future work.

Lessons learnt (regarding the data)	Examples	Suggestions for the future

Database Client is working properly and loading data from the data base to ToSIA works fine		
To be able to gather consistent and reliable data, it is extremely important to assure that everybody involved in the data collection process uses common terminology and understands the data requirements	- transformation factors - harvest residues and biomass definitions	- training on data collection issues - further development of the data collection protocols
It is also important to define exactly what should be reported to avoid double counting and assure data completeness.	- Gross Value Added calculation M2/M3	- training on data collection issues - further development of the data collection protocols - visualisation tools for the database Client - creation of a glossary of commonly used EFORWOOD vocabulary
UNITS: – Reporting units should be consistent for each process – Indicator measurement units needs to be consistent along the chain to make it possible to aggregate the values	- Energy units: MJ, kWh, litres of oil…	- training on data collection issues - further development of the data collection protocols - restrictions will be implemented in the database Client - visualisation tools for the database Client

With the Single FWCs it was demonstrated that the current ToSIA version is able to calculate material flows along a Single FWC and calculate and assess indicator values (economic, social and environmental) for processes along the FWC. In the regional-defined spruce chain the loop chain calculation was implemented for the first time. Two alternative management options were implemented as separate chains and the results of these chains were compared. An in-depth analysis was not, however, meaningful due to the incompleteness of the data.

The presentation of sustainability indicator results in this report includes the complete material flow within specified Single FWC system boundaries. The material flow along the FWC gets smaller whenever processes produce also by-products that leave the system boundaries of the selected FWC. For example, both the Scandinavian Scots pine and the German Spruce management produce also pulp wood, but the pulp and paper value chain were not fully included in these Single FWC analyses. Consequently, the absolute sustainability indicator values for the material flow inside system boundaries over-represents M2 and M3 processes. Future work will include the development of allocation principles to assign an appropriate loading of sustainability indicator values to the different main and side products of the FWC.

With ToSIA it is possible to compare two alternative management practises within the same chain and their effects on the indicators. However, it is important to notice that comparing the forest defined pine chain and the regional-defined spruce chain would not be meaningful taken that the boundaries of these chains are totally different.

An important question is how to verify the tool and the results in the future? Different approaches are currently discussed and tools are under development for that purpose. First of all, the database client that has already proved to be useful in data collection will still be further developed to involve visualisation of the data to make mistakes and misunderstandings in data collection more transparent. More exact data collection protocols will be developed and training for those who collect data will be arranged. ToSIA itself will include different small tools for checking the data quality and completeness. After all, the reliability of the ToSIA results will depend on the data provided to the model. The evaluation of the reliability of the each single data value will be impossible. But several verifications using model comparisons and independent statistical data are planned for the next phase of ToSIA applications for Case studies with multiple FWCs.

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ANNEX 1 Technical description of the second ToSIA – Prototype

This section describes in brief the structure of ToSIA prototype 2.

ToSIA Engine

In the following sections only a brief introduction to the modelling approach of the ToSIA Engine is given. For a more comprehensive description, please refer to the deliverable D1.4.3.

The implementation of the ToSIA model is at the heart of the EFORWOOD project. It is where a significant part of the actual processing of data takes place. The portion of ToSIA that is visible to the user is naturally the user interface; the ToSIA Engine contains the actual implementation of the ToSIA model. When the user performs actions which affect the FWCs under study in the user interface, these are translated into commands to the engine to perform. The engine returns information corresponding to the actions it has performed and the new information can now be displayed by the user interface.

ToSIA input data and data structure in ToSIA prototype 2

ToSIA receives its input data from the EFORWOOD database. Limited input is also provided by the user of the software. The user's input is composed of commands given via the user interface and possibly by manual revision of input data or entry of new data.

Data from the database is loaded into ToSIA when the application is started. This data must strictly follow the agreed-upon format, in order for the loading of the data to be successful. The transfer of information from the EFORWOOD database to ToSIA is handled via XML[1] –files, which can be generated using the functionality provided by the EFORWOOD Database Client

The data derived from the database for input into ToSIA is categorized into two groups: static data and dynamic data. The static data can perhaps be characterized as an unordered group of data on processes, grouped by module and stage of FWC. Dynamic data is formed by picking processes from static data, and putting them in a structure which links together processes and assigns the product flowing in each linkage between two processes.

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[1] XML – eXtensible Markup Language is used of data exchange in form of structured text. For more information please see http://www.w3.org/XML

The state of flow calculation in ToSIA prototype 2

The flow calculation in the second prototype was refined based on the first prototype. The two main improvements since the first prototype have been adopting the use of Carbon as the measure of flow amount and implementation of loop calculation specifically designed for the BW Spruce case.

Several minor improvements have also been made to give more information to the user about the results of flow calculation and present it in a more aggregated way. For example, the flows going outside the system boundary (flows leaving the chain) are collected and shown together.

The use of conversion factors to convert the (Carbon) flows into the reporting unit for indicator calculation has had a deep impact on handling and storing the flow information. The incoming flows need to be processed in Carbon, but each incoming flow needs to have its own unique conversion into reporting unit. The information relating to the calculation of input and output flows is presented to the user in the text-based-interface. This information is such as the summing up and conversion of input flows and also visually showing the actual calculations, and the division of output by output shares.

The development of new functionality has to a big degree been correlated with the progress of data collection. As new data became available, new functionality taking advantage of the new data could be implemented. The new data itself often also provoked changes, as it has in many cases revealed weaknesses in design or forwarded new data requirement.

In prototype 2 the most complex calculations are those dealing with the calculation of the material flows in a chain. Flow calculation, where through recycling or some other kind of re-use where input is based on the process' own output products, is the most difficult to implement.

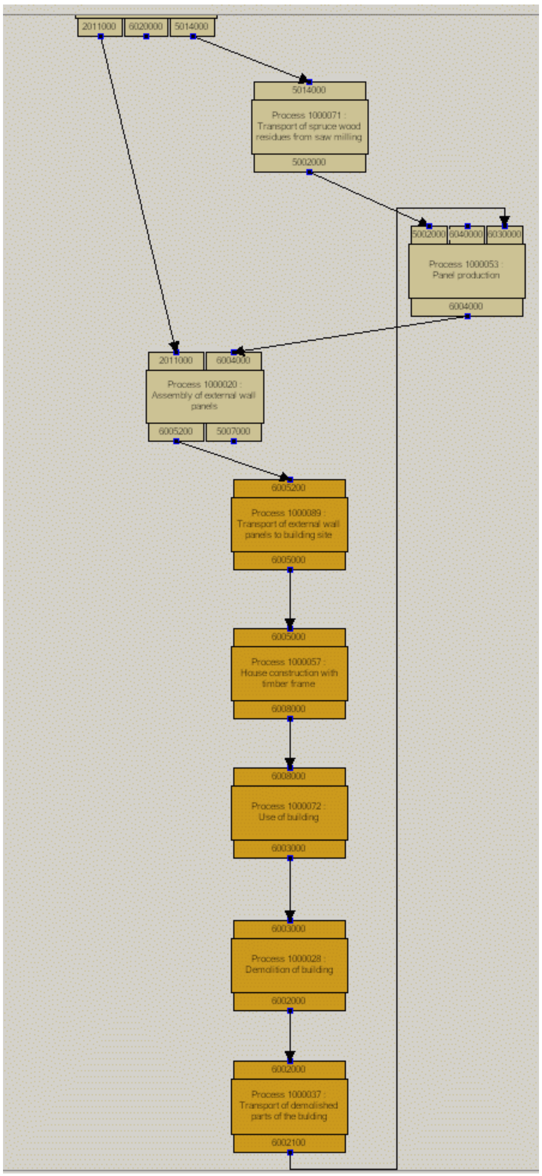
ToSIA calculations were discussed in more detail in Deliverable D1.4.3. The definition of loop calculation in Deliverable D1.4.3 was done by giving the equation used to derive the total output of the process receiving the flow from the loop-structure as input. This was given as follows:

$$x = \frac{(A + B + ...Z)}{(1 - P)},$$

where A..Z are the different amounts of flow into ROOT, which is the process receiving the output of a loop as input. P is a PATHSHARE that is the proportion of ROOT's output that the final process in the loop gives as output, passing it to ROOT as input.

In ToSIA prototype 2, the goal was to implement the calculation of flows in loop-structures, in all reasonable cases. This did not happen. Instead, work on a general solution to this problem lead to the discovery of new issues that need to be resolved before loop calculation can be successfully implemented. For example the current specification of the loop in the BW Spruce chain is not compatible with the algorithmic solution of applying equation 1 given here. A customized solution was provided for resolving the loop in the spruce chain. A more specific definition of what kind of loop-structures can be allowed is now clearly needed. The problems associated with for example the current BW Spruce case are demonstrated in Table 9.

Table 9. Description of the difficulties with loops in the BW Spruce case.



In the loop shown here from the spruce chain, all the material in the end of the chain (demolished house) is reused in panel production. To put it simply, the problem is that more material comes from the reuse than the panel production can handle. If the amount of input to the Panel Production process is based on the amount of output from the ”Transport of demolished parts of the building” -process and as the amount of the demolished building is bigger than then the amount of panels produced, then when we attempt to correct the calculation based on a new input mass amount to the Panel Production from demolishment in an iterative way, the inputs and outputs of the Panel Production increase toward infinity with each iteration. This is a somewhat unsolvable calculation problem.

Part of this issue can be avoided, because we do have the “input share” for products by which we can limit the excess material that comes into a process. However, the same calculation problem remains, as we cannot count the amount of excess that is left unused.

This case demonstrates the need for more exact specification of “allowed loop structures”, which needs to be handled prior to the next round of data collection and chain specification.

The next version of ToSIA will be implemented with the OpenMI methodologies, which will allow for handling of flow calculation using the OpenMI mechanisms, which are significantly different from the current approach. It was thus not seen an effective use of resources to implement a general solution for loop-flow calculation in ToSIA prototype 2. The updated requirements for allowed loop structures will thus be defined for the OpenMI version of ToSIA that is under development.

The key assumptions or limitations on flow calculation in prototype 2 are:

- the output product shares are known, they define the amount of material flow into each consecutive process.
- As the output shares dictate the flow amounts downstream, the input shares are not yet used to limit excess incoming flow according to input shares (input shares are used currently only to solve loops and assess the size of external input flow quantities into the chain)
- If the FWC contains loop-structure (e.g. recycling loops), the process receiving the result of the loop as input must always have at least one other input source
- FWCs with loops inside loops are not allowed
- A process can be used in a chain only once, otherwise the process id is not unique in the chain!!
- Not allowed: more than one (chain)external input to one process with same product id
- Not allowed: more than one product leaving the chain from one process with same product id
- Not allowed: initialization flow's flow type must be an unique flow as an outflow (no other flows with same id)

Details of the indicator value calculation

A crucial concept of ToSIA is that all processes in different stages of the chain occur simultaneously because the impact assessment is calculated for one specific year. Thus the dynamic evolution of the forest (Figure 10) is not explicitly considered (Figure 11). In the case of Forest resource management (M2), it has some specific consequences. If we consider a sustainable forest management strategy, in one specific year, one area is cut but there is a lot of forest resources growing at the same time to enable a sustainable harvest flow over time e.g. to be able to cut 20 ha per year we will need a forest resource of 60 ha undergoing regeneration when regeneration takes three years. Thus, when collecting data for a particular year, for M2 we need to multiply the area being considered at a yearly level by the time period needed to perform each process (Figure 11). As all the indicator values (environmental, economic and social) for processes in M2 are reported per year (indicator unit ha^{-1} $year^{-1}$), the result will be a calculation of the indicator values per area studied (area needed to produce a certain amount of product for M3).

As in M2 we are referring to hectares of forest per process (stage of development), the reference unit used in M2 differs from the one used for the rest of the chain. “Tons of organic carbon” is used in M3 to M5 by the ToSIA software and converted to reporting units using conversion factors. A transformation factor (different from conversion factors) is applied after the final process in M2 to convert M2 ha into tons of organic carbon. The transformation factor includes all carbon that is used as input to the first processes of M3 (C in stem wood and C in residues).

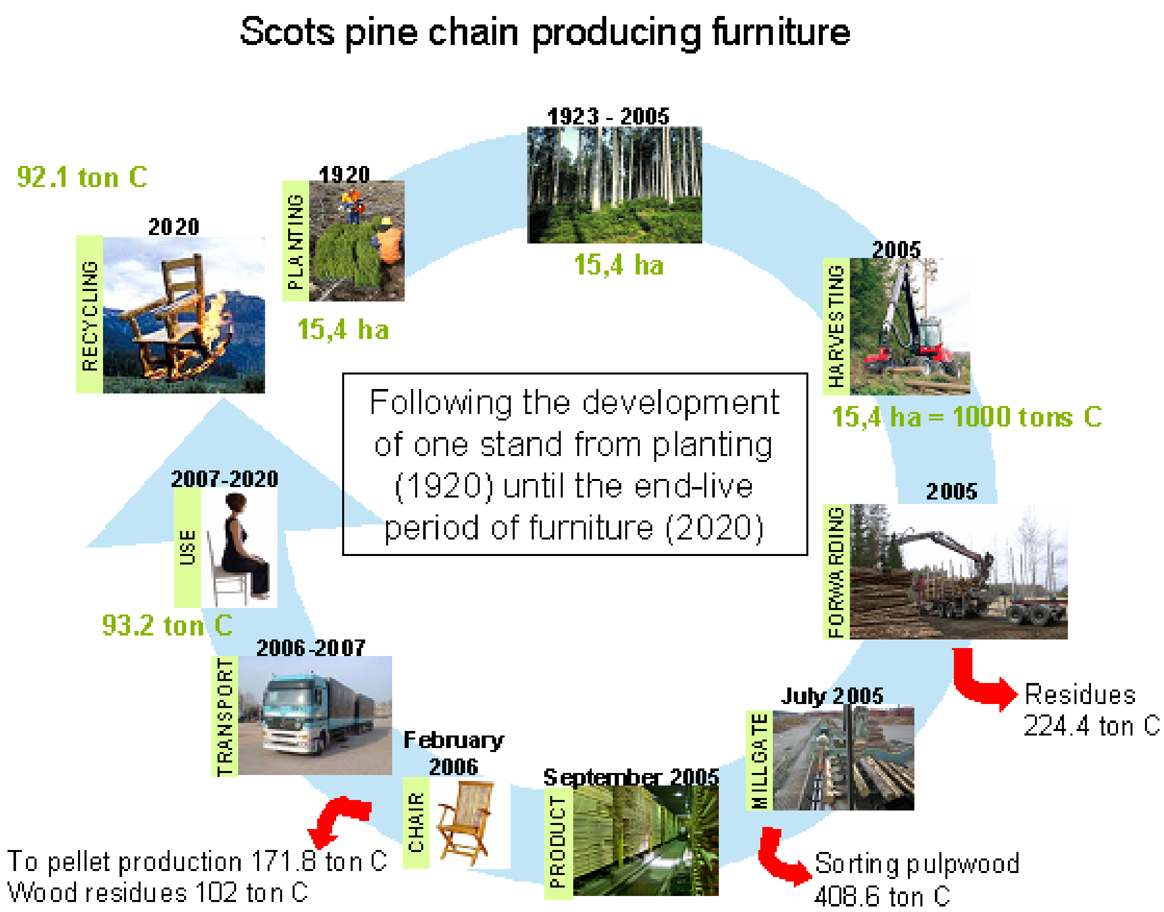


Figure 10. View of the test chain with final clear-cutting in pine forests of Scandinavia for furniture showing the development of one stand since planting until the end of life of the product. A rotation length of 85 years is assumed for an average stand in the region.

For illustrating this exercise, we may consider an even-aged Pine test chain with final clear-cutting at the age of 85 years in Scandinavia. Imagine that we assume that the total amount of C that flows from M2 to M3 is 1000 tons of C. Therefore to achieve this amount of carbon we need to cut 15,4 ha per year. The main idea here is that indicators are linked to reference units (15,4 ha/year) times the duration of different processes in M2 or "time needed to complete a phase of development" (time multiplier), i.e. 3 years for the regeneration period, 7 years for the development of a stand in the young phase, 10 years of development of a planted stand in the medium phase and 65 years for development of a planted stand in the adult phase. These times differ between geographical areas, tree species and management regimes. As the indicators are reported per year, this time multiplier is needed in ToSIA for those processes that last more than one year in order to make calculations along the whole FWC. Typically these long-lasting processes are in M2. Continuing the example, for indicator "LI 16b Carbon sequestration in woody living biomass" during the young stage, the amount of tons of carbon/year stored by each ha of young forest needs to be multiplied by 154 (15,4 ha of reference units*10 years of duration).

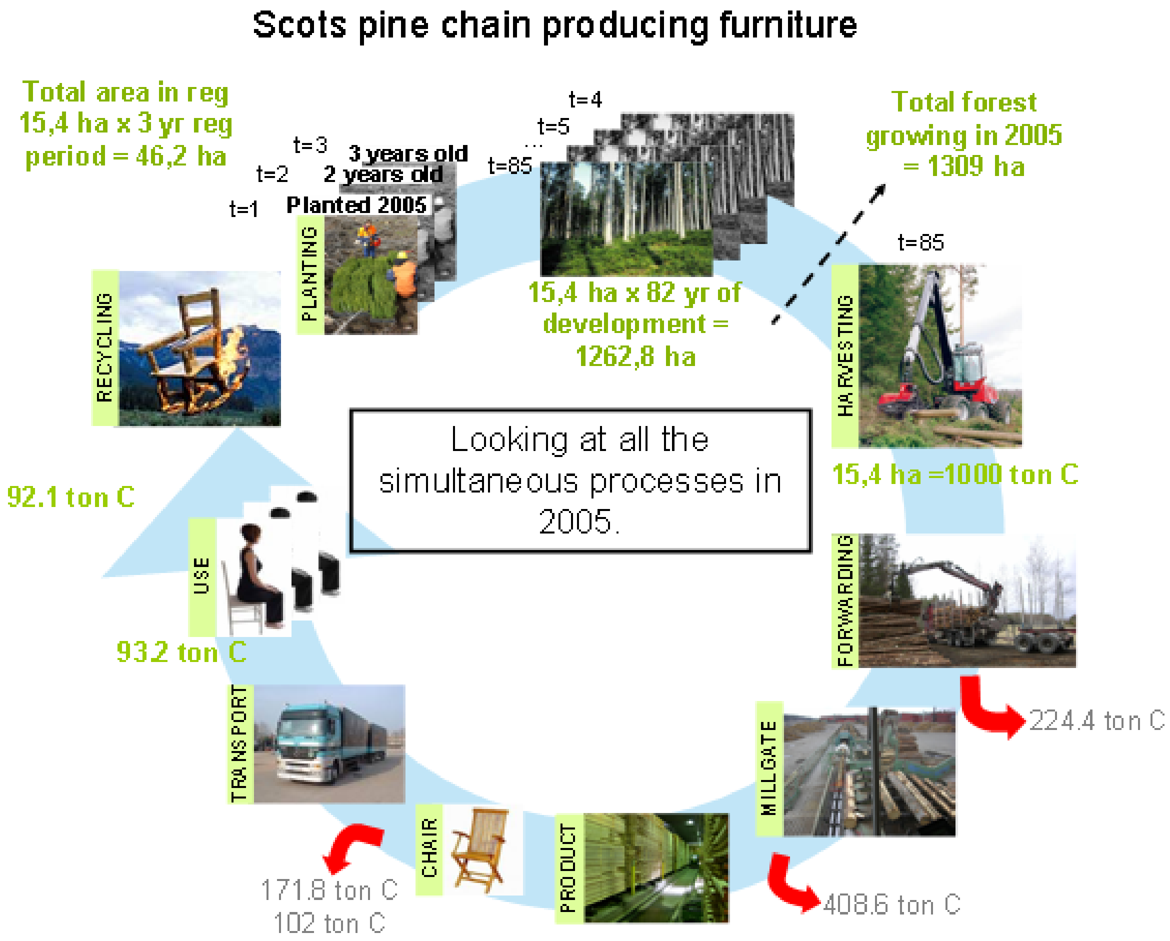


Figure 11. View of the test chain with final clear-cutting in pine forests of Scandinavia for furniture showing the time perspective of the EFORWOOD project. A rotation length of 85 years is assumed for an average stand in the region.

At this phase the calculated process indicator values are computed multiplying the total flow of input material to the process (in reporting units) by the indicator value per material flow. At a later phase in ToSIA development, when response functions will be employed to describe indicator behaviour, the calculation will be somewhat more complex. However, even then there will only be the additional step of identifying the right point along the response curve and then proceeding with calculation as in the prototype with multiplication with flow.

Also, as a next step of ToSIA development a new calculation procedure for M2 will be implemented in the calculation of regional values for the reference year. This will then allow using forest inventories for a region to report real forest resource data instead of only standard management plans.

User interface in ToSIA prototype 2

In prototype 2 a very simple graphical user interface was created to simplify production of results. A text-based version dating back to the first prototype 1 is also available.

In the graphical user interface, the user can select the chains to be calculated from just three options. The interface displays the aggregated results for the core indicator set as text and exports calculated process level sustainability impact values into a csv-file with the chain's id in the name of the file.

When the text-based interface is used, a more diverse set of information is accessible. When using the text-based interface there is information available on material flow amounts at the process level, information on calculation results of sustainability indicator impacts at both the process level and aggregated for the whole chain. There is functionality provided to view nearly all information that is stored or calculated in ToSIA. Also, exporting the calculation results as Excel-readable CSV-files was added.

This version of ToSIA does not aim to be a user-friendly version including a graphical user interface. ToSIA prototype 2 is essentially just used to validate central EFORWOOD concepts and assist in defining the evolving data specifications, which are a requirement for successful data collection. This in turn is needed to complete the required functionality as specified in the definition of work.

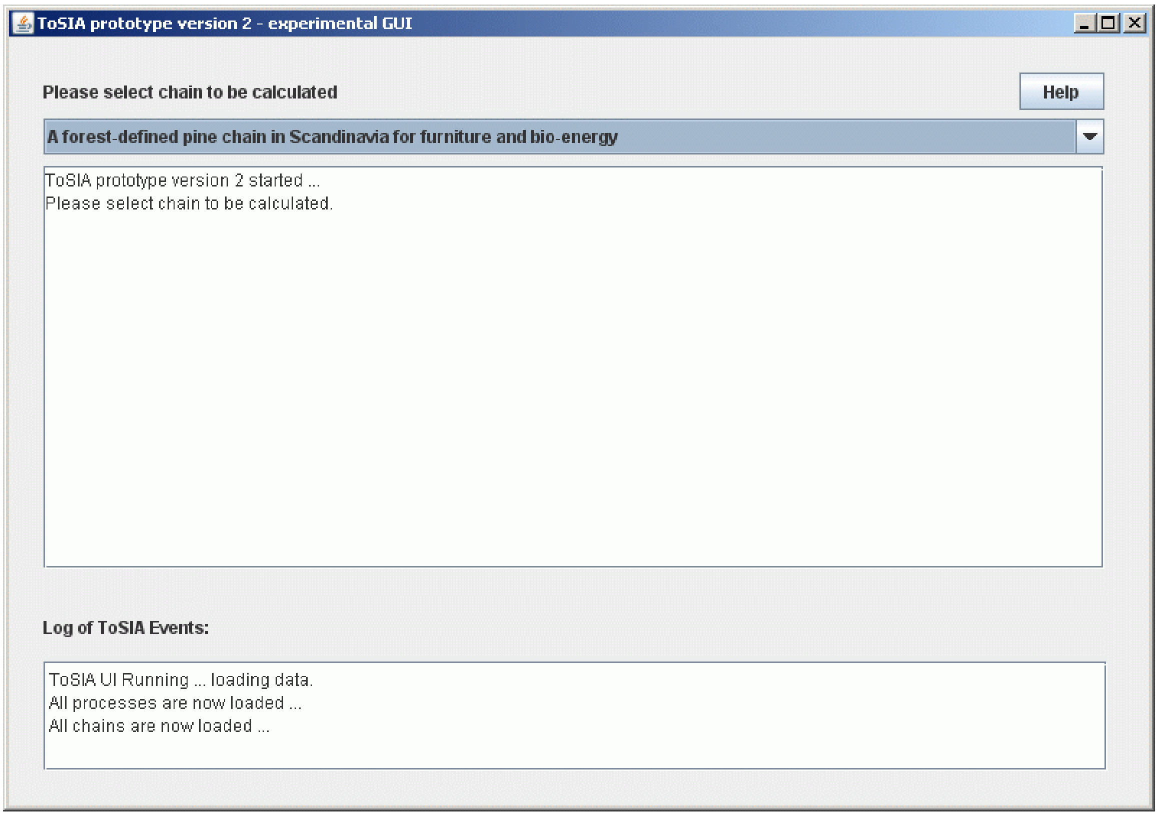
ANNEX 2 Quick Guide to Running the ToSIA Prototype 2

Prerequisites:

- the Java runtime engine (JRE) version that was used in producing the prototype was 1.6.0_04 (Java(TM) 2 Runtime Environment, Standard Edition (build 1.6.0_04-b12)). Optimally, the version should be this or newer – the version can be checked by giving the command: `java -version` at a command prompt.
- The provided zip-file should have been extracted with pathnames; the files `Eforwood_processes_UTF8.xml` and `Eforwood_chains_UTF8.xml` should be located in the same directory as the executable (`tosia_prototype_2.jar`). The directory should also contain a subdirectory "lib".

To start ToSIA :

Double click the file `tosia_prototype_2.jar`, and a very basic graphical version of ToSIA starts up. The chains that are available to be run are loaded from the xml file. When you run a chain, detailed results per process are put into two separate csv-files in the same directory from where the program was run. The aggregated results for the whole chain are shown on screen. A small help is available. Reproducing the results seen on screen can be accomplished by exiting and restarting the program.



To start ToSIA with detailed information on calculations in text mode:

In Windows: open the command prompt (Run – and type “cmd”), change to the directory where ToSIA is located (e.g. “cd tosia”) and give the following command:

```
java -jar tosia_prototype_2.jar
```

When ToSIA is started in this manner, further information in the progress of the calculation, especially regarding the calculation of flow amounts, for each process can be accessed. (Note: the buffer size of the Command Prompt –window (the black screen) should in most cases be increased to 9999 lines, so that all the information written to screen stays accessible. This can be done from the Properties settings for the window.)

When ToSIA is running, the following commands are available to the user:

- **c** - to list contents of chains
- **m** - to list contents of all modules
- **e** - to end running ToSIA
- **h** - to read this listing of commands
- **p** – to calculate results of: A forest-defined pine chain in Scandinavia for furniture and bio-energy
- **s** - to calculate results of: Regional-defined spruce chain - natural regeneration
- **t** - to calculate results of: Regional-defined spruce chain - planting regeneration

Notes

As there is no sophisticated error checking present in the prototype, the correct calculation is assumed to take place when data following the specified xml format is used as input, and that the chains for calculation have been correctly initialized with a flow on the M2-M3 boundary. In the files provided with the zip package this has already been done, but if you download a new set of xml files from the EFORWOOD database to be used as input to ToSIA, the initialization flows need to be added.

To get detailed information about the ToSIA Prototype 2 implementation structure, please open the HTML documentation of the implementation from (inside this directory at \javadoc\index.html)

When viewing the csv files in MS Excel, you should import the data instead of opening them. This way you get a proper structure for the data. You should use the comma as value delimiter in the options. With OpenOffice just opening the document works.

ANNEX 3 Terms and definitions

Here are definitions of the terms that are used in the EFORWOOD project, particularly those that are in connection with the ToSIA modelling framework.

AGGREGATION of INDICATORS

- Vertical aggregation
  For some common indicators of the whole FWC the total over the process steps may be calculated in ToSIA to assess the performance of a selected FWC regarding a target indicator. This mode of aggregation can be accomplished without MCA and CBA respectively.
- Horizontal aggregation
  There are two levels of horizontal aggregation: i) if the studied FWC contains alternative process options for the same process step (e.g. transport with varying distance or transport mode) it may be useful to average or otherwise aggregate a target indicator such as greenhouse gas emissions; ii) using MCA or CBA valuation methods it is possible to aggregate different indicators for one or several process step(s) within a module or stage [see Stage].
- Full aggregation
  Aggregation of different sustainability indicators along the whole FWC using MCA or CBA valuation methods. Full aggregation means to accept trade-offs among sustainability dimensions and phases of a FWC.

CASE STUDY; REGIONAL CASES; REGIONAL FWC

Case Studies in EFORWOOD refer to the application of ToSIA in the second phase of EFORWOOD to ensembles of FWCs, which are regionally specified. Depending on the specification of the regional FWC, either the forest resources, the industrial production capacity, the product consumption, or the entire FWC are restricted to a geographical region (see Specification of a FWC). The EFORWOOD project will study at least three Case studies: (i) Scandinavian production Case study, (ii) Baden-Württemberg Case study, and (iii) Iberian Peninsula consumption Case study.

CBA (Cost Benefit Analysis)

In EFORWOOD, CBA will be applied to analyse the differences between e.g. two optional FWCs which a decision maker may generate through two different policies. The CBA is performed from a social perspective, that is, the comparison is done using the concepts of social benefit and social cost, as EFORWOOD strives to include also the social benefits of externalities like carbon sequestration and recreation as well as the social costs of e.g. pollution with NOx's, SO's etc. It is important to stress that CBA involves a comparison of several alternatives and it cannot be applied if no alternatives are specified.

CONVERSION FACTORS

Mass in tons of Carbon is used as the information carrier for FWCs in ToSIA. The information carrier is the base unit (reference unit), which is used internal to the application, to ensure that all information is comparable, and consistent. The material flows between forest resource management and consecutive processes along the FWC are products which contain a percentage of Carbon. Each individual product needs a conversion factor from original mass to mass of contained pure Carbon.

Additional conversion factors will be established to enable the ToSIA output using different units such as m^3 of roundwood or tons of marketable end-products. Within M2, forest growth will be reported on a per hectare basis, thus need arises to convert from area-based figures to mass based figures. All conversion factors need to be supplied by module experts.

EFORWOOD DATABASE (TOSIA)
The purpose of the database is to serve ToSIA as a source of data needed for calculations of indicator values and material flows along the FWC. Original data about processes will be supplied by M2-M5. The database is structured in several hierarchical levels reflecting the structure of the FWC. The database structure consists of stages organized in modules. Each stage contains alternative processes. Processes are linked with values of parameters, products and values of indicators.

DECISION MAKER
If an individual has choices to make, he or she can be considered as a decision maker (Keeney & Raiffa, 1993). In a strict sense a decision maker is empowered to make a final choice.

In the context of EFORWOOD, for instance, among others the following institutions/persons using TOSIA could hold the role of a decision maker: an officer at the Commission, a national policy maker, a manager in the forest industry or in another company involved in the FWC, a forest owner.

EUROPEAN FWC
European FWC refers to the application of ToSIA in the final stage of the EFORWOOD project to the main FWCs in Europe (EU 25 plus EFTA countries Norway and Switzerland). The definition of work stated the ambition to include 60-80% of the European wood flows in the sustainability impact assessment.

FORESTRY-WOOD CHAIN (FWC)
A FWC represents a set of Processes by which resources from forests are converted into services and products. In EFORWOOD, FWCs are dealt with at various levels. The highest level is the European FWC which is defined as EU 25 plus Norway and Switzerland (EFTA countries). There are many kinds of FWCs at the more detailed levels. They can be geographically defined or linked to the main processing chains (paper, wood-products, bio-energy etc.).

see also Test Chain, Case Study, European FWC, Specification of a FWC

INDICATOR
Indicators show something or point to something. An indicator can thus be defined as: "A parameter, or a value derived from parameters, which points to / provides information about / describes the state of a phenomenon / environment / area with a significance extending beyond that directly associated with a parameter value (OECD, 1993)." "An indicator is a means devised to reduce the large quantity of data down to its simplest form retaining essential meaning for the questions that are being asked of the data (Ott, 1978)".
The term indicator should be differentiated from other terms that are sometimes used similarly or confused with this: Criteria / Impact Issue/ Sustainability Theme.

Within the EFORWOOD project, indicator values per material flow are taken from the database client, where the set of indicator are introduced. In ToSIA, the calculated process indicator values are determined based on the material flow through the process and the indicator values per material flow from the database. Calculated module and FWC indicator values are then determined by aggregating the calculated process indicator values along the chain taking into account the system boundaries selected by the user.

MCA (MULTI-CRITERIA ANALYSIS)
MCA is the overarching term for a set of methods which are specifically designed to (i) take explicit account of multiple, conflicting indicators, criteria or objectives, (ii) to structure a decision problem where the focus is on the comparison of a finite number of alternatives/alternative courses of action with the aim to identify the most preferable option, (iii) to provide a formal model for such problems that can serve as a focus for discussion, and (iv) to offer a process that leads to rational, justifiable, and explainable decisions. The process of multi-criteria analysis is to (i) develop a finite number of alternatives, (ii) to choose one or more methods for examining them, (iii) to evaluate and compare these alternatives with regard to set of criteria and indicators, and (iii) making recommendations with respect to the objective of the evaluation. In EFORWOOD optional FWCs are compared across a set of indicators with regard to their impact on sustainable development.

MODELS

Models are simplified and structured (often mathematical) expressions of reality. Models are used for deriving relevant characteristics based on empirical data, such as the environmental impacts of a FWC process expressed in terms of indicator values. Models are also used to describe the inter-linkages of various processes within the chains, or relationship between regional chains. In EFORWOOD, Models are used in the Modules to calculate Indicator values and changes in material flows under different Scenarios.

MODULE
Modules are the subprojects of EFORWOOD. Modules combine processes together in logical groups (see also Processes and Stages of the FWC). Modules present the highest hierarchical level of a FWC. Modules are handled by different groups of institutions and so data and understanding of processes may differ from module to module. However, from the ToSIA database point of view, the module is just one of the classifiers for the processes. There is no difference in database structure between the modules.

PREFERENCES
In the context of sustainability impact assessment, preferences are subjective values of stakeholders involved in a decision making process especially to describe (i) the importance of decision criteria and indicators, and/or (ii) the preferentiality of a specific indicator value over another with regard to the evaluation objective (here: SIA). Preferences may be expressed by ordinal or cardinal rank order.

PRODUCT
Products are the mass-based inputs and outputs of processes, such as spruce logs or finished wood furniture. The functional purpose of products is to link together

processes to form chain structures. Products are expressed in mass units and for each product the conversion factor, for converting it to different units (e.g. tons of C, m^3, ha) should be known. Processes can also receive input products from outside of the FWC system boundaries (e.g. non-wood material used in furniture manufacturing).

PROCESS (in a FWC); **PRODUCTION PROCESS**

The most important element of a FWC is a Process. Transformation of energy and materials takes place in a Process. In a process wood material will change its appearance and/or move to another location**.** Every process requires inputs and produces outputs. Inputs for each Process in a chain are supplied by outputs of previous Processes. Therefore in case of the FWC we call inputs and outputs simply Products. Processes include planting trees, stand treatments, harvesting, transport, sawing, pulping, papermaking, printing, packaging, recycling, and energy production – or when needed subsets thereof.

SCENARIOS

Scenario in the context of EFORWOOD is a combination of internal or external drivers and their impacts to the FWC. Different classes of drivers will be studied in the later stages of the project:

- Drivers external from EU and European FWC (e.g. market demand for forest products in China; climate change)
- Drivers external from European FWC, but EU internal (e.g. EU subsidies for renewable energies)
- Drivers internal of the FWC (technical development)

The scenarios will result in alternative FWCs with different sustainability impacts compared to the current FWCs. Scenarios impacts will be evaluated with MCA and CBA evaluation methods (see CBA and MCA).

SPECIFICATION of a FWC

ToSIA will be designed in such a way that different perspectives for the sustainability impact assessment are possible. In the diagram below alternative ways of defining FWCs are presented (Figure 13). The idea is to make it possible to analyze sustainability impacts of for example:

a) the total use of a specific forest type or the entire forest in a particular region
b) an industry process where input products come from different sources and the products are later further refined
c) the composition of processes resulting in a single end-product (in the case of a Single FWC) or the consumption of wood-based products in a target region (in a regional Case study).

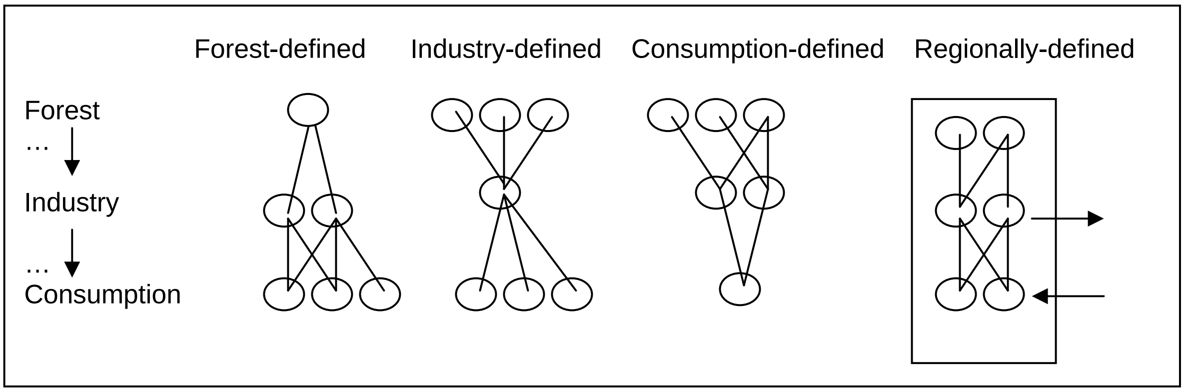


Figure 13. Alternative ways of defining FWCs.

The system boundaries of the analysis vary depending on the specification of the FWC. In a forest-defined FWC, the forest resource is specified (e.g. Scots pine forests in Northern Sweden) and only this resource is followed throughout the FWC. In a consumption-defined regional Case study, the consumed wood-based products of a target region are specified and the FWCs needed for their production are followed backwards to the forest resources. In the case of a regionally-defined FWC, only the forest resources, production processes and consumption that occur within the selected region will be analysed.

STAGE of a FWC
A module consists of several Stages. Stages define natural steps in the FWC. One stage can be characterized by alternative processes, which means that scenarios can be produced by switching to different processes within the same stage. There are no consecutive processes within one Stage (i.e. process of harvesting and the process of wood transportation should be placed in two separate Stages).

STAKEHOLDER
In a general sense, stakeholders consist of all people/institutions associated with a decision-making process by holding a stake in the decision making process, being affected by decisions or by contributing their knowledge and ideas in the process. Standard stakeholders include decision makers, experts, planners, other stakeholders having special interests and analysts responsible for the preparations and managing of the process.

SUSTAINABLE DEVELOPMENT:

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own need. (World Commission on Environment and Development. 1987; adopted by the EU Strategy for Sustainable Development).

SUSTAINABILITY IMPACT ASSESSMENT (SIA):
The impact of changes in production technologies or changes in material flows on sustainability, measured by derivation of economic, social and environmental indicators for FWCs or their parts.

SUSTAINABILITY PILLAR; SUSTAINABILITY DIMENSION
The EU Sustainable Development Strategy, first adopted by the European Council in Göteborg (2001) and renewed in 2006 (EU Commission Document 10117/06), defines as key objectives three sustainability pillars: ENVIRONMENTAL PROTECTION, SOCIAL EQUITY AND COHESION, and ECONOMIC PROSPERITY. The three pillars of sustainability are often referred to as different dimensions of sustainability: the environmental, social, and economic dimensions of sustainability.

TEST CHAIN
A test chain is a fixed combination of processes forming a Single FWC that uses pre-defined material flows, which results in fixed values for sustainability impacts. Test chains were used to develop ToSIA and to gain experience with the sustainability impact assessment of simple FWCs. After the EFORWOOD week in Portugal in month 13, the Test Chains have been slightly revised into Single FWCs, which are embedded into the three Case Studies in EFORWOOD phase II. All major EFORWOOD concepts such as indicator selection, sustainability assessment of the current FWC and scenario analysis of alternative FWCs will be applied first to the Test Chains/Single FWCs. Three Test Chains were studied in EFORWOOD:

- A regionally-defined spruce chain in Baden-Württemberg.
- A forest-defined pine chain in Scandinavia for furniture and bio-energy.
- A product-defined fine paper/newspaper chain mainly based on eucalyptus and including recycling.

ToSIA (Tool for Sustainability Impact Assessment)
Is a tool used for SIA of FWCs. ToSIA is a dynamic FWC pathway analysis model, which aggregates indicator values to estimate overall sustainability of a FWC. It describes the production processes within the FWCs, attaches quantitative indicator values to processes and derives the aggregated values for sustainability indicators.

ToSIA-FWC: basic version of ToSIA.

ToSIA+E: In addition to ToSIA-FWC, this version includes components for evaluation of optional FWCs and their trade-offs, using MCA and CBA methods.

ToSIA-U: Is a web-based simplified, user friendly version of ToSIA+E intended for industries, stakeholders and policy makers.

ANNEX 4 List of processes and product output shares

Table A1. The Forest-defined pine chain in Scandinavia for furniture and bio-energy including the processes names, the output products shares, the reporting units used in the different processes and the conversion factor values (tons of C/reporting unit).

Module	ProcessID	ProcessName	OutputProduct	ProductShare	ReportingUnit	Conv Factor
	1000090	Scarification and planting of pine	Regenerated site	1	ha	-
	1000077	Development of planted pine stand in young phase with 1 pre-commercial thinning	Young stand	1	ha	-
M2 - Forest resources	1000077	Development of planted pine stand in young phase with 1 pre-commercial thinning	Trees to be removed in pre-commercial thinning	1	ha	-
management	1000048	Development of planted pine stand in medium phase	Medium aged stand	1	ha	-
	1000048	Development of planted pine stand in medium phase	Trees marked for thinning	1	ha	-
	1000087	Development of planted pine stand in adult phase	Mature pine forest ready for clear felling without green tree retention	1	ha	-
	1000003	Clear cut with large single-grip harvester	Pulpwood: (incl. downgraded fuelwood)	0.33	m3 sub	0.2120
	1000003	Clear cut with large single-grip harvester	Harvest residues left on site	0.21	m3 sub	0.2090
	1000003	Clear cut with large single-grip harvester	Saw logs (incl. downgraded fuelwood)	0.46	m3 sub	0.2220
	1000027	Pre-commercial thinning of planted pine stand in young phase	Harvest residues left on site	1	ha	0.2150
	1000034	Felling with large harvester	Harvest residues left on site	0.23	m3 sub	0.2110
	1000034	Felling with large harvester	Saw logs (incl. downgraded fuelwood)	0.17	m3 sub	0.2150
	1000034	Felling with large harvester	Pulpwood: (incl. downgraded fuelwood)	0.6	m3 sub	0.2100
	1000046	Forwarding of pine after thinning	Pulpwood (fuelwood incl.) piled at the road side acc to size and quality	0.78	m3 sub	0.2100
	1000046	Forwarding of pine after thinning	Sawlogs (fuelwood incl.) piled at the road side acc to size and quality	0.22	m3 sub	0.2150
M3 - Forest to industry	1000058	Forwarding of pine after final felling	Pulpwood (fuelwood incl.) piled at the road side acc to size and quality	0.42	m3 sub	0.2120
interactions	1000058	Forwarding of pine after final felling	Sawlogs (fuelwood incl.) piled at the road side acc to size and quality	0.58	m3 sub	0.2220
	1000101	Transport by 60t truck with crane acc to assortment	Timber (fuelwood incl.) transported to saw mill	1	tons	0.2220
	1000102	Transport by 60t truck with crane acc to assortment	Pulpwood (fuelwood incl.) transported to pulpmill	1	tons	0.2120
	1000103	Transport by 60t truck with crane acc to assortment	Timber (fuelwood incl.) transported to saw mill	1	tons	0.2150
	1000104	Transport by 60t truck with crane acc to assortment	Pulpwood (fuelwood incl.) transported to pulpmill	1	tons	0.2100
	1000025	Final measuring and sorting of pine logs according to quality at sawmill	Fuelwood	0.05	m3	0.2220
	1000025	Final measuring and sorting of pine logs according to quality at sawmill	Saw logs	0.95	ha	0.2220
	1000109	Final measuring and sorting acc. to quality at pulpmill	Fuelwood	0.05	m3 sub	0.2120
	1000109	Final measuring and sorting acc. to quality at pulpmill	Pulpwood	0.95	m3 sub	0.2120
	1000116	Final measuring and sorting acc. to quality at sawmill	Fuelwood	0.05	m3 sub	0.2150
	1000116	Final measuring and sorting acc. to quality at sawmill	Saw logs	0.95	m3 sub	0.2150
	1000118	Final measuring and sorting acc. to quality at pulpmill	Fuelwood	0.05	m3 sub	0.2100
	1000118	Final measuring and sorting acc. to quality at pulpmill	Pulpwood	0.95	m3 sub	0.2100
	1000004	Pine timber conversion at saw mil	Wood residues ready for pellet production	0.35	m3	0.2450
	1000004	Pine timber conversion at saw mil	Other pine wood residues	0.05	m3	0.2450
	1000004	Pine timber conversion at saw mil	Sawn timber	0.6	m3	0.2450
	1000007	Pellet production	Pellets	1	tons of pellets	0.4500
M4 - Processing and	1000065	Production of chair components	Other pine wood residues	0.2	m3	0.2450
manufactoring	1000065	Production of chair components	By products, chips, dust, etc. used in pellet production	0.2	m3	0.2450
	1000065	Production of chair components	Chair components	0.6	m3	0.2450
	1000084	Transport of pine wood residues	Wood residues ready for pellet production	1	tons	0.2479
	1000085	Transport of sawn pine timber	Sawn timber ready for manufacturing	1	tons	0.4711
	1000093	Chair production	Chair	0.7	m3	0.2450
	1000093	Chair production	Waste	0.3	m3	0.2450
	1000056	Transportation of pellets to home scale use	Pellets at final destination	1	tons of pellets	0.4500
	1000052	Transportation of chair to retail	Chair at retail	1	tons	0.4803
	1000035	Consumption, energy heat production	Ashe	0.004	tons of pellets	0
M5 - Industry to	1000035	Consumption, energy heat production	Energy (electricity and heat)	0.996	tons of pellets	0.0958
consumer interactions	1000044	Transportation of chair to customer	Chair at final destination	1	tons	0.4803
	1000022	Using the chair	Used chair	1	tons	0.4803
	1000024	Transport of chair to end of life	Used chair at incinerator	1	tons	0.4803
	1000060	Incineration with energy recovery and ash diposal	Ashe	0.004	m3	0
	1000060	Incineration with energy recovery and ash diposal	Energy (electricity and heat)	0.996	m3	0

Table A2. The regional-defined spruce chain - natural regeneration including the processes names, the output products shares, the reporting unit used in the different processes and the conversion factor values (tons of C/reporting unit).

Module	ProcessID	ProcessName	OutputProduct	ProductShare	ReportingUnit	Conv factor
	1000008	Regeneration with natural regeneration and weeding	Spruce forest regenerated naturally	1	ha	-
	1000023	Development of naturally regenerated spruce stand in young phase with 1 precommercial thinning	Trees marked for precommercial thinning	1	ha	-
	1000023	Development of naturally regenerated spruce stand in young phase with 1 precommercial thinning	Young stand	1	ha	-
M2 - Forest resources	1000086	Development of naturally regenerated spruce stand in medium phase	Trees marked for 1.and 2. thinning	1	ha	-
management	1000086	Development of naturally regenerated spruce stand in medium phase	Trees marked for 3.-6. thinnin	1	ha	-
	1000086	Development of naturally regenerated spruce stand in medium phase	Medium aged stand	1	ha	-
	1000092	Development of naturally regenerated spruce stand in adult phase	Trees marked for 5. and 6. thinning	1	ha	-
	1000092	Development of naturally regenerated spruce stand in adult phase	Mature stand ready for harvest	1	ha	-
	1000099	3.-6. thinning: motor-manual cutting, debranching measuring and sorting acc. to quality	Harvest residues, diameter < 8cm	0.19	m3 sub	0.2074
	1000099	3.-6. thinning: motor-manual cutting, debranching measuring and sorting acc. to quality	Pole length tree (for later cross-cutting): top diameter >8 cm	0.81	m3 sub	0.2074
	1000100	1.-2. thinning: motor-manual cutting, debranching measuring and sorting acc. to quality	Pole length tree (for later cross-cutting): top diameter >8 cm	0.77	m3 sub	0.2074
M3 - Forest to industry	1000100	1.-2. thinning: motor-manual cutting, debranching measuring and sorting acc. to quality	Harvest residues, diameter < 8cm	0.23	m3 sub	0.2074
interactions	1000119	Pre-commercial thinning operations	Harvest residues	1	m3 sub	0.2074
	1000075	Skidding with double-winch wheel skidder	Pole length log piled at road side acc to assortment, size and quality	0.92	m3 sub	0.2074
	1000075	Skidding with double-winch wheel skidder	Pulpwood piled at the road side acc to size and quality	0.08	m3 sub	0.2074
	1000108	Skidding with double-winch wheel skidder	Pole length log piled at road side acc to assortment, size and quality	0.16	m3 sub	0.2074
	1000108	Skidding with double-winch wheel skidder	Pulpwood piled at the road side acc to size and quality	0.84	m3 sub	0.2074
	1000079	Transport by truck for long timber with crane	Timber transported to saw mill	1	m3 sub	0.2074
	1000076	Final measuring and sorting, long timber	Roundwood sorted and stacked at log yard	1	m3	0.2074
	1000068	Saw milling	Sawn timber	0.6	m3	0.2150
M4 - Processing and	1000068	Saw milling	Off cuts	0.2	m3	0.2150
manufactoring	1000068	Saw milling	Wood residues	0.2	m3	0.2150
	1000020	Assembly of external wall panels	Waste	0.1	m3	0.2150
	1000020	Assembly of external wall panels	External wall panels	0.9	m3	0.2150
	1000053	Panel production	Wood panels	1	m^3	0.2150
	1000071	Transport of spruce wood residues from saw milling	Wood residues ready for panel production	1	tons	0.2500
	1000089	Transport of external wall panels to building site	External wall panels at building site	1	tons	0.4498
M5 - Industry to	1000028	Demolition of building	Used timber frame	1	tons	0.4614
consumer interactions	1000057	House construction with timber frame	Timber frame building	1	m3	0.2150
	1000072	Use of building	Building at end-of-life	1	m3	0.2150
	1000037	Transport of demolished parts of the bulding	Dismantled timberframe at recoverry site	1	tons	0.4614

Table A3. The regional-defined spruce chain - planting regeneration including the processes names, the output products shares, the reporting unit used in the different processes and the conversion factor values (tons of C/reporting unit)..

Module	ProcessID	ProcessName	OutputProduct	ProductShare	ReportingUnit	Conv factor
M2 - Forest resources management	1000113	Regeneration with planting and weeding	Regenerated site	1	ha	-
	1000010	Development of planted spruce stand in young phase with 2 pre-commercial thinnings	Young stand	1	ha	-
	1000010	Development of planted spruce stand in young phase with 2 pre-commercial thinnings	Trees marked for precommercial thinning	1	ha	-
	1000067	Development of planted spruce stand in medium phase	Medium aged stand	1	ha	-
	1000067	Development of planted spruce stand in medium phase	Trees marked for 1.and 2. thinning	1	ha	-
	1000067	Development of planted spruce stand in medium phase	Trees marked for 3. and 4. thinning	1	ha	-
	1000098	Mature stand development	Mature stand ready for harvest	1	ha	-
	1000098	Mature stand development	Trees marked for 5. and 6. thinning	1	ha	-
M3 - Forest to industry interactions	1000106	1.-2. thinning: full-mechanized cutting with medium harvester, debranching, evtl. pre-sorting	Harvest residues	0.30	m3 sub	0.2074
	1000106	1.-2. thinning: full-mechanized cutting with medium harvester, debranching, evtl. pre-sorting	Pulpwood: Top diameter >8cm	0.45	m3 sub	0.2074
	1000106	1.-2. thinning: full-mechanized cutting with medium harvester, debranching, evtl. pre-sorting	Saw logs short: Top diameter >12cm	0.25	m3 sub	0.2074
	1000107	3.-6. thinning: full-mechanized cutting with large harvester, debranching, evtl. pre-sorting	Saw logs short: Top diameter >12cm	0.55	m3 sub	0.2074
	1000107	3.-6. thinning: full-mechanized cutting with large harvester, debranching, evtl. pre-sorting	Harvest residues	0.21	m3 sub	0.2074
	1000107	3.-6. thinning: full-mechanized cutting with large harvester, debranching, evtl. pre-sorting	Pulpwood: Top diameter >8cm	0.24	m3 sub	0.2074
	1000119	Pre-commercial thinning operations	Harvest residues	1	m3 sub	0.2074
	1000018	Forwarding with medium forwarder after 1st. Thinning	Sawlogs piled at the road side acc to size and quality	0.36	m3 sub	0.2074
	1000018	Forwarding with medium forwarder after 1st. Thinning	Pulpwood piled at the road side acc to size and quality	0.64	tons	0.2074
	1000063	Forwarding with medium forwarder after 2nd. Thinning	Pulpwood piled at the road side acc to size and quality	0.31	m3 sub	0.2074
	1000063	Forwarding with medium forwarder after 2nd. Thinning	Sawlogs piled at the road side acc to size and quality	0.69	m3 sub	0.2074
	1000042	Transport by truck for short timber with crane	Timber transported to saw mill	1	m3 sub	0.2074
	1000082	Final measuring and sorting, short timber	Roundwood sorted and stacked at log yard	1	m3 sub	0.2074
M4 - Processing and manufactoring	1000068	Saw milling	Sawn timber	0.60	m3	0.2150
	1000068	Saw milling	Wood residues	0.20	m3	0.2150
	1000068	Saw milling	Off cuts	0.20	m3	0.2150
	1000020	Assembly of external wall panels	External wall panels	0.90	m3	0.2150
	1000020	Assembly of external wall panels	Waste	0.10	m3	0.2150
	1000053	Panel production	Wood panels	1	m^3	0.2150
	1000071	Transport of spruce wood residues from saw milling	Wood residues ready for panel production	1	tons	0.2500
M5 - Industry to consumer interactions	1000089	Transport of external wall panels to building site	External wall panels at building site	1	tons	0.4498
	1000028	Demolition of building	Used timber frame	1	tons	0.4614
	1000057	House construction with timber frame	Timber frame building	1	m3	0.2150
	1000072	Use of building	Building at end-of-life	1	m3	0.2150
	1000037	Transport of demolished parts of the bulding	Dismantled timberframe at recoverry site	1	tons	0.4614

Table A4. The product-defined fine paper/newspaper chain including recycling including the processes names, the output products shares and the conversion factor values (tons of C/reporting unit). This chain is still uncompleted.

Module	ProcessID	ProcessName	OutputProduct	ProductShare	Value
	1000014	Application of fertilizers and thinning of eucalyptus saplings on second and third coppice rotation	Fertilized Eucalyptus coppice stand before coppice with 8 shoots per stool	1	-
	1000036	Site preparation, weed control and planting of eucalyptus	Regenerated Eucalyptus site	1	-
	1000090	Scarification and planting of pine	Regenerated site	1	-
	1000031	Development of coppiced eucalyptus stand in young phase with harrowing and fertilization	Eucalyptus coppice stand after young development phase, 2nd or 3rd coppice rotation	1	-
	1000077	Development of planted pine stand in young phase with 1 pre-commercial thinning	Trees to be removed in pre-commercial thinning	1	-
M2 - Forest resources management	1000077	Development of planted pine stand in young phase with 1 pre-commercial thinning	Young stand	1	-
	1000091	Development of planted eucalyptus in young phase with 3 weed controls and 2 fertilizations	Eucalyptus planted stand after young development phase	1	-
	1000002	Development of coppiced eucalyptus stand in medium phase with harrowing	Eucalyptus 2nd or 3rd rotation coppice ready for harvesting	1	-
	1000048	Development of planted pine stand in medium phase	Trees marked for thinning	1	-
	1000048	Development of planted pine stand in medium phase	Medium aged stand	1	-
	1000062	Development of planted eucalyptus stand in medium phase	Eucalyptus 1st rotation coppice ready for harvesting	1	-
	1000087	Development of planted pine stand in adult phase	Mature pine forest ready for clear felling without green tree retention	1	-
	1000003	Clear cut with large single-grip harvester	Saw logs (incl. downgraded fuelwood)	0.46	0.2220
	1000003	Clear cut with large single-grip harvester	Pulpwood: (incl. downgraded fuelwood)	0.33	0.2120
	1000003	Clear cut with large single-grip harvester	Harvest residues left on site	0.21	0.2090
	1000030	Harvesting of planted eucalyptus with medium single-grip harvester	Eucalyptus standard length logs pulpwood. Top diameter over bark >7cm, length 2,5 m	0.77	0.2919
	1000030	Harvesting of planted eucalyptus with medium single-grip harvester	Harvest residues left on site	0.23	0.2919
	1000030	Harvesting of planted eucalyptus with medium single-grip harvester	Harvested coppice site	1	0.2920
	1000034	Felling with large harvester	Harvest residues left on site	0.23	0.2110
	1000034	Felling with large harvester	Pulpwood: (incl. downgraded fuelwood)	0.6	0.2100
	1000034	Felling with large harvester	Saw logs (incl. downgraded fuelwood)	0.17	0.2150
	1000070	Harvesting of coppice eucalyptus with small single-grip harvester	Harvest residues left on site	0.23	0.2919
	1000070	Harvesting of coppice eucalyptus with small single-grip harvester	Harvested coppice site	1	0.2920
	1000070	Harvesting of coppice eucalyptus with small single-grip harvester	Eucalyptus standard length logs pulpwood. Top diameter over bark >7cm, length 2,5 m	0.77	0.2919
M3 - Forest to industry interactions	1000136	Pre-commercial thinning of 6-7 shoots per stool on second and third rotation	Eucalyptus coppice stand with 1 - 2 shoots per stool after regeneration development phase	1	0.2920
	1000136	Pre-commercial thinning of 6-7 shoots per stool on second and third rotation	Harvest residues left on site	1	0.2919
	1000046	Forwarding of pine after thinning	Pulpwood (fuelwood incl.) piled at the road side acc to size and quality	0.78	0.2100
	1000046	Forwarding of pine after thinning	Sawlogs (fuelwood incl.) piled at the road side acc to size and quality	0.22	0.2150
	1000058	Forwarding of pine after final felling	Pulpwood (fuelwood incl.) piled at the road side acc to size and quality	0.42	0.2120
	1000058	Forwarding of pine after final felling	Sawlogs (fuelwood incl.) piled at the road side acc to size and quality	0.58	0.2220
	1000080	Forwarding by medium forwarder (12 tons)	Eucalyptus timber piled on truck	1	0.2919
	1000074	Transport by truck with crane	Eucalyptus pulpwood delivered to pulp mill	1	0.2919
	1000102	Transport by 60t truck with crane acc to assortment	Pulpwood (fuelwood incl.) transported to pulpmill	1	0.2120
	1000104	Transport by 60t truck with crane acc to assortment	Pulpwood (fuelwood incl.) transported to pulpmill	1	0.2100
	1000073	Final measuring, grading and sorting	Eucalyptus pulpwood ready for pulp production	1	0.2919
	1000109	Final measuring and sorting acc. to quality at pulpmill	Fuelwood	0.05	0.2120
	1000109	Final measuring and sorting acc. to quality at pulpmill	Pulpwood	0.95	0.2120
	1000118	Final measuring and sorting acc. to quality at pulpmill	Pulpwood	0.95	0.2100
	1000118	Final measuring and sorting acc. to quality at pulpmill	Fuelwood	0.05	0.2100
	1000019	Integrated pulp and paper production	Fine paper	1	0.3000
M4 - Processing and manufactoring	1000096	Pulping (de-inking) and newsprint production from recovered fibres	Newsprint paper	1	0.4800
	1000097	Pulp transport to Portugal	Market pulp ready for paper production	1	0.4000
	1000110	Market kraft pulp mill in Sweden	Market pulp	1	0.4000
	1000129	Transportation of newsprint ES	Newsprint paper at printer	1	0.4800
	1000132	Distribution of newspaper to subscribers	Distributed newspaper	1	0.4800
	1000133	Whole sale distribution of fine paper ES	Fine paper at office	1	0.3000
	1000134	Transportation of recovered paper	Collected recovered paper at mill gate	1	0.3900
	1000125	Newspaper printing - Cold-set web offset ES	Newspaper printed and ready for distribution	1	0.4800
	1000130	Office printing laser b/w	Printed fine paper	1	0.3000
	1000131	Information - use	Collected used paper	0.58	0.3000
M5 - Industry to consumer interactions	1000131	Information - use	Used paper in mixed waste	0.42	0.3000
	1000127	Information/entertainment - use of newspaper ES	Used paper in mixed waste	0.42	0.4800
	1000127	Information/entertainment - use of newspaper ES	Collected used paper	0.58	0.4800
	1000121	Transport of used paper in mixed waste	Used paper in mixed waste	1	0.3000
	1000122	Transport of used paper in mixed waste 2	Used paper in mixed waste	1	0.4800
	1000123	Incineration of waste paper	Ashe	-	-
	1000123	Incineration of waste paper	Energy (electricity and heat)	-	-
	1000124	Landfill of used paper	Ashe	-	-
	1000124	Landfill of used paper	Energy (electricity and heat)	-	-
	1000128	Separate collection	Paper waste	0	-
	1000128	Separate collection	Recovered Paper	1	0.3900