EFORWOOD
Tools for Sustainability Impact Assessment

Documentation of ToSIA developments and ToSIA version 1.0

Wendelin Werhahn-Mees, Diana Vötter, Tommi Suominen and Marcus Lindner

EFI Technical Report 47, 2011

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and
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Publisher: European Forest Institute
Torikatu 34, FI-80100 Joensuu, Finland
Email: publications@efi.int
http://www.efi.int

Editor-in-Chief: Risto Päivinen

Preface

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

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

Uppsala in November 2010

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EFORWOOD

Sustainability Impact Assessment of the Forestry - Wood Chain

Project no. 518128

EFORWOOD

Tools for Sustainability Impact Assessment

Instrument: IP

Thematic Priority: 6.3 Global Change and Ecosystems

Deliverable D1.4.6 (update)
Documentation of ToSIA developments up to month 52
and
Deliverable D1.4.5 (update)
ToSIA version 1.0

Also includes originally planned Deliverable D1.4.9 (Report describing ToSIA applications studying sustainability impact assessments of scenarios of changing sustainability applied to case studies and European FWC analysis)

Due date of deliverable: Months 39 and 48
Actual submission date: Month 54

Start date of project: 011105
Duration: 4 years

Organisation name of lead contractor for this deliverable:
European Forest Institute (EFI)

Final version

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)

Dissemination Level

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

UPDATE Deliverable D1.4.6 (update)
Documentation of ToSIA developments up to month 43

Deliverable D1.4.5 (update)
ToSIA version 1.0- Case Study applications

Includes also originally planned Deliverable D1.4.9 (Report describing ToSIA applications studying sustainability impact assessments of scenarios of changing sustainability applied to case studies and European FWC analysis)

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WP 1.4 ToSIA - Tools for Sustainability Impact Assessment

Abstract:

One of the main objectives of the EFORWOOD project is to develop a decision support tool for Sustainability impact assessment of the European Forestry Wood Chains (FWC). The Tool for Sustainability Impact Assessment (ToSIA) will be besides the data collected (database and Database Client) 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 D1.4.5 and D 1.4.6 is documented. Furthermore the basic functionalities of ToSIA will be shown. In addition, the Case Studies used in EFORWOOD are described and the procedure of calculating indicators values for the FWCs is explained.
In this late phase of the project a lot of emphasis has been put on the verification of the data collected. Some of the methodologies developed and results of this work will be presented as well in this document.

Key words: decision support tool, sustainability impact assessment, Case Studies, ToSIA, data verification

Acronyms

BWC	Baden-Württemberg Case Study
C	Carbon
cf	Conversion factor
DBC	Database Client
EU FWC	European Forestry Wood Chain
FWC	Forestry Wood Chain
GUI	Graphical User Interface
ha	Hectare
ICS	Iberian Case Study
m3	cubic meter
M2	Forest resource Module
M3	Forest to industry interaction Module
M4	Manufacturing, ind. processing and converting Module
M5	Industry to consumer interaction Module
SCS	Scandinavian Case Study
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. 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 implementation of 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 since the last deliverable version submitted on the 1. 2. 2008. 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; see also Lindner et al.(in press) for a general tool description.

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 (DBC) 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 the relative indicator value of the selected indicators.

Application of ToSIA for Case Study analysis

The Case Study analyses are after the Single Chain applications the first complex applications of ToSIA in the EFORWOOD project. However also the Case Studies serve to test ToSIA and to demonstrate the use of the model.

The aim of the Case Studies was to model the FWCs in different European regions. Three Case Study applications have been developed using different perspectives of the Forestry-Wood Chain which have consequences for the definition of system boundaries for the analysis:

- The "**Scandinavian Case Study**" (SCS) is forest defined and aims to describe the network of the Forestry-Wood Chains in Västerbotten, Sweden including part of the processing and consumption outside of the region.
- The "**Baden-Württemberg Case Study**" (BWC) is regional defined and aims to describe the network of forestry-wood chains in Baden-Württemberg. Imports into and exports out of the region are excluded from the system. This means that the sustainability impacts of the material flow outside the region are not considered. Furthermore the case study shows the cross-links between the different production lines of sawmilling, pulp & paper and the bio-energy sector.
- The objective of the "**Iberian Case Study**" (ICS) is to develop a model of the Iberian market of wood based products. The approach is consumer driven so main focus of the case study will consider final fibre-based products.

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. Validation routines have been developed to automatically check inconsistencies in the reported data.

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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).

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

1) **Single FWC** applications - done
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 (see also Lindner et al.(in press)). 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 for Case Studies (current version 4.1.5) 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 D1.2.6.

The purpose of this deliverable report is to document the progress in ToSIA development since the release of D1.4.6 in February 2008. The case studies used in the EFORWOOD project are described and using examples from these chains, the procedure of calculating indicator values for the FWCs is explained. A compendium of commonly used terms and definitions is documented in the Annex.

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 and Lindner, 2008){Päivinen, submitted #4358}. 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.

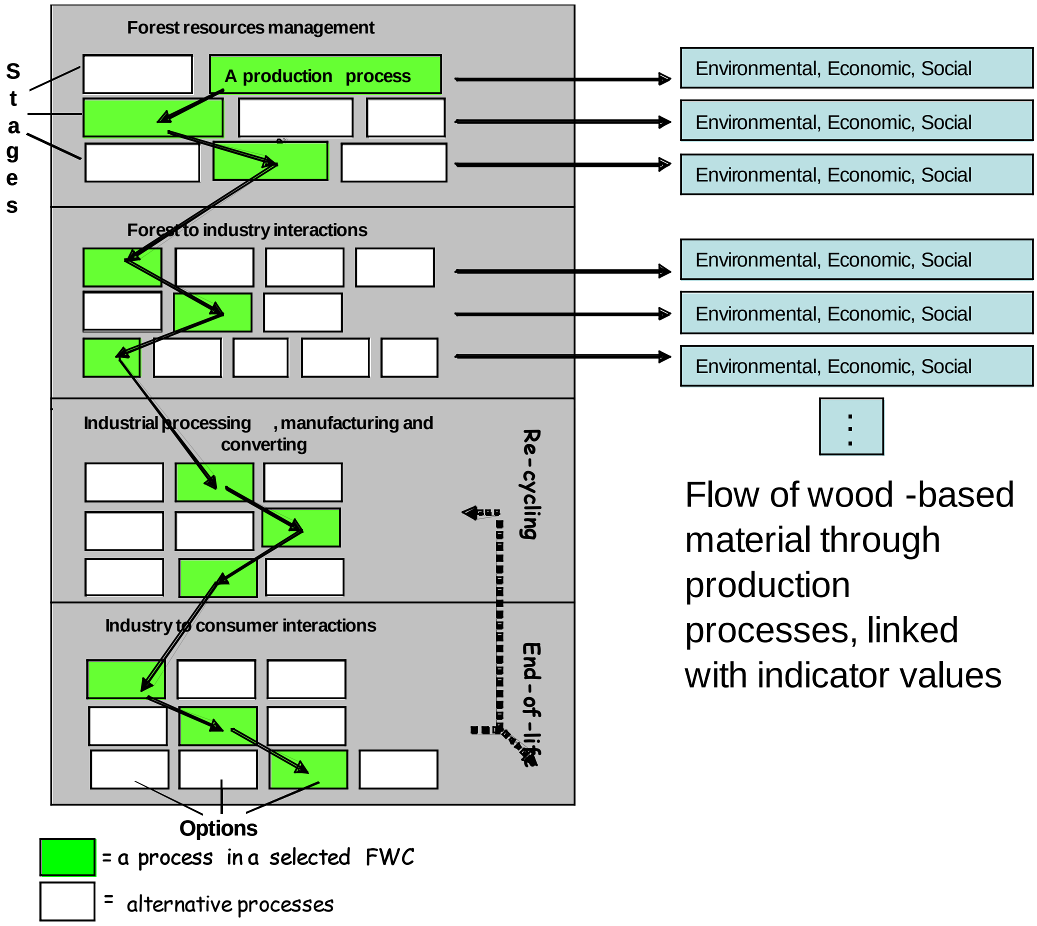


Figure 1. This is the methodological framework to assess the sustainability impacts of FWCs. The boxes (white, green) represent processes in one FWC. Each process is linked with a set of environmental, economic and social indicators.

EFORWOOD is focusing on the assessment of sustainability impacts by comparing alternative FWCs in terms of their indicator performance. The work flow of conducting sustainability impact assessments with ToSIA is depicted in Figure 2.

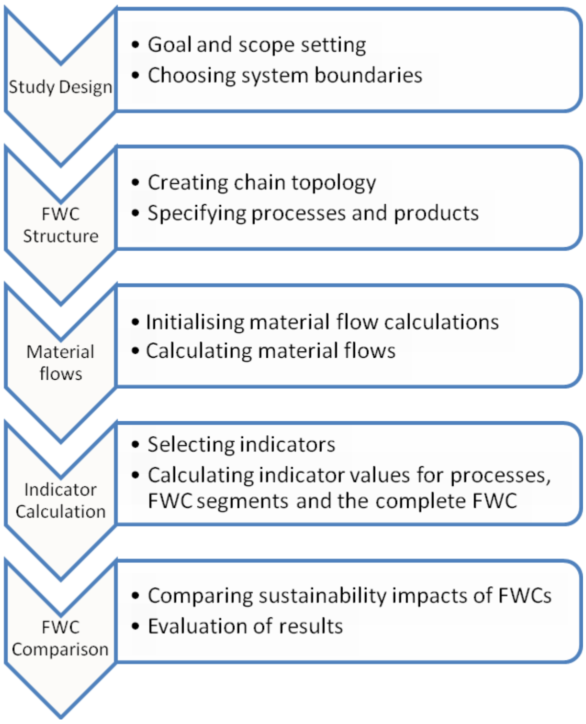


Figure 2. Work flow indicating steps in conducting a sustainability impact assessment for the FWC using ToSIA.

There is no timeline integrated into ToSIA by default. Instead, the space for time replacement concept is used: all processes at different stages of the chain are calculated simultaneously as the impact assessment is done for the whole FWC for one specific year.

2.1 Defining chain structure

2.1.1 Topology

The topology describes the structure of the FWC, which is composed of production processes, input and output products, and their linkages. The topology of the case studies is a bit more complex than the one of the Single FWCs. Depending on the definition of the system boundaries, not all impacts are in included in a assessment sustainability, e.g. in the region-defined Baden-Württemberg case study, system boundaries follow the geographical borders. System boundaries are however not restricted to geographic boundaries, but can also be thematic boundaries, defining the content of a studied case and what is excluded from it. A forest-defined case study applies different geographical system boundaries for different parts of the FWC: in the Scandinavian case study, forest resources are confined to Västerbotten, Sweden, whereas other FWC segments may expand outside of this region. Several value chains, such as fibre chains, solid wood chains and bio-energy chains are included in the different case studies. Import and export of products quantify the volume of products entering and leaving geographical system boundaries of the analysis and they are specified in indicator 3.1.1 for imports and 3.2.1 for exports (total volume per process). The system boundaries of the different case studies are explained in detail in chapter 5 of this document.

The case studies include also alternative topologies for various time steps (reference futures and scenarios).

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.

In comparison to other SIA models the system boundary of the ToSIA approach as applied in EFORWOOD is limited to the forest sector. Sustainability impacts of products outside of the forest sector are therefore not taken into consideration, which is a fundamental difference to the approach taken in the Life Cycle Analysis or the Input Output Model as illustrated in Figure XXX.

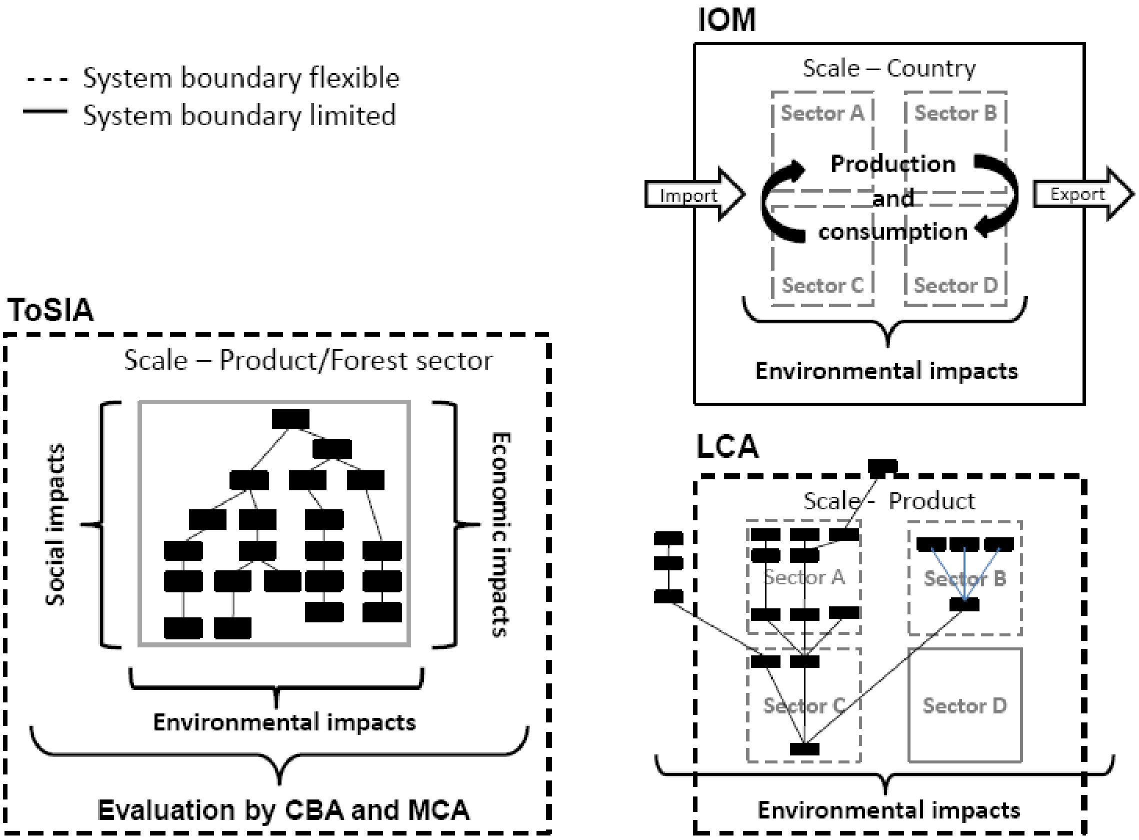


Figure 3. Simplified illustration of the tool for sustainability impact assessment (ToSIA), input output modeling (IOM) and environmental life-cycle assessment (LCA). Big boxes represent geographical system boundaries (e.g. country) within which all studied impacts are to be covered. Small boxes represent production sectors. LCA follows singular production chains as far as possible, also over the country and sector boarders. IOM links the environmental impacts to trade statistic. Sustainability impact assessment done by ToSIA concentrates on the forest-based sector and covers also social and economic impacts that can then be evaluated by cost-benefit analysis, multi-criteria analysis of policy analysis.

In order to specify and visualise the topology of a FWC the so called Database Client was developed. Using the Database Client the structure of the FWC can be built and the data inserted.

2.1.2 Database and Database Client

The FWC is understood in ToSIA as a flexible structure linking production processes with input and output products. This structure is flexible 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. Figure XXX shows a screen shot of the EFORWOOD Database Client.

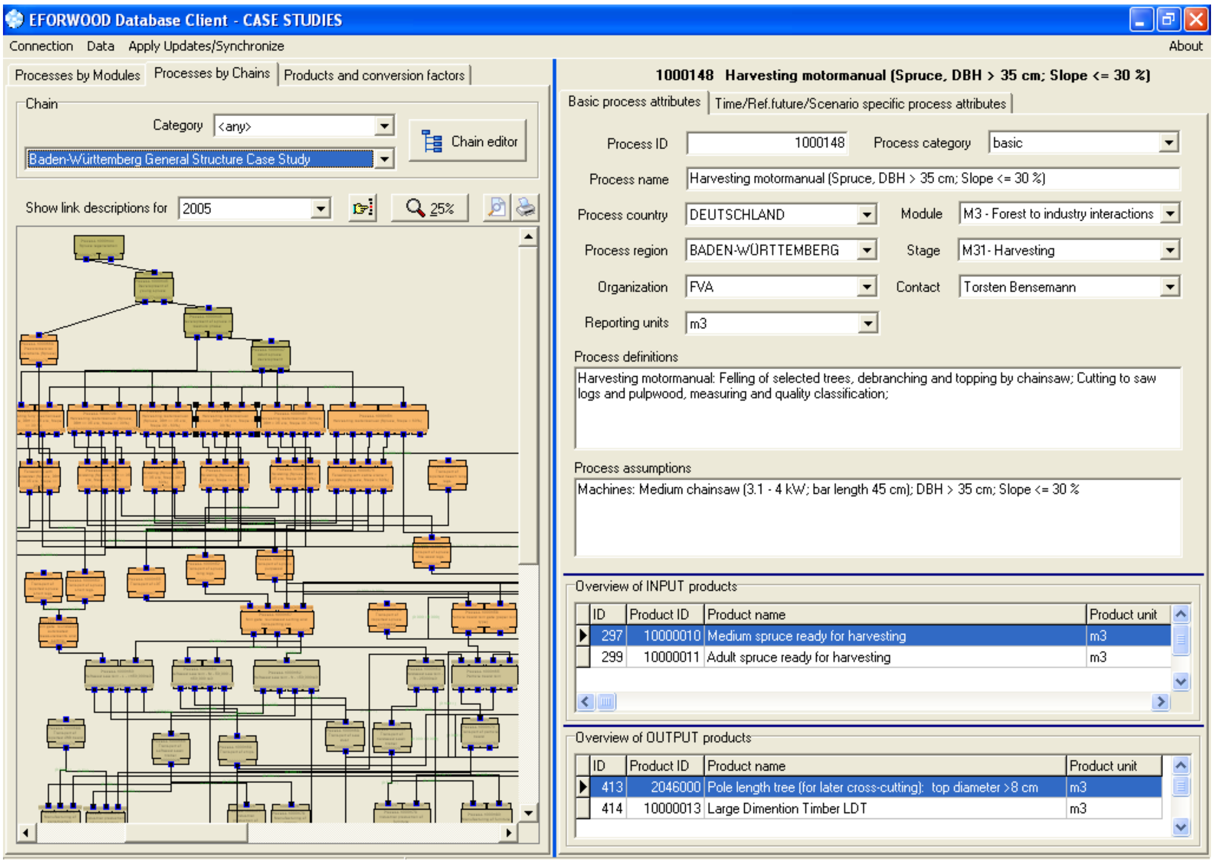


Figure 4. Screen shot of the EFORWOOD Database Client. On the left hand side a visualisation of the Baden-Wuerttemberg Case Study. The coloured boxed represent single processes; the black lines are the linkages between the processes/products of a process. On the right hand side information on the selected process is displayed.

The basic components needed to build up the topology of a FWC 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 changes its appearance and/or moves 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 the case of the FWC, both inputs and outputs are called products. Example of processes are - planting trees, stand treatments, harvesting, transport, sawing, pulping, papermaking, printing, etc.. In the database, processes carry individual process IDs. The indicator values are linked to processes. Processes can be re-used multiple times in the same as well as in other chains. However, the information carried by the processes will always be exactly the same.

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. Processes can also receive input products from outside of the FWC system boundaries (e.g. non-wood material used in furniture manufacturing). In the database, products also carry individual product IDs. Linked to those products is a set of conversion factors;

- to tons of C
- to tons
- to m^3ub
- to ha

Product also can be re-used, however, they all carry the same information, i.e. characteristics and conversion factors assigned to the product. This minimises the workload of building chains and reduces the potential for mistakes. Conversion factors to EURO are not linked as they can vary for one product within different timesteps and regions.

c) Links
As soon as two processes with its input and output product are defined the processes are linked with each other. A link symbolizes where the output material flow of one process is going to.

2.2 Different scopes of ToSIA applications

ToSIA is designed in such a way that different perspectives for the sustainability impact assessment are possible. Figure 5 illustrates alternative ways of defining FWCs. The idea is to make it possible to analyze sustainability impacts of for example:

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

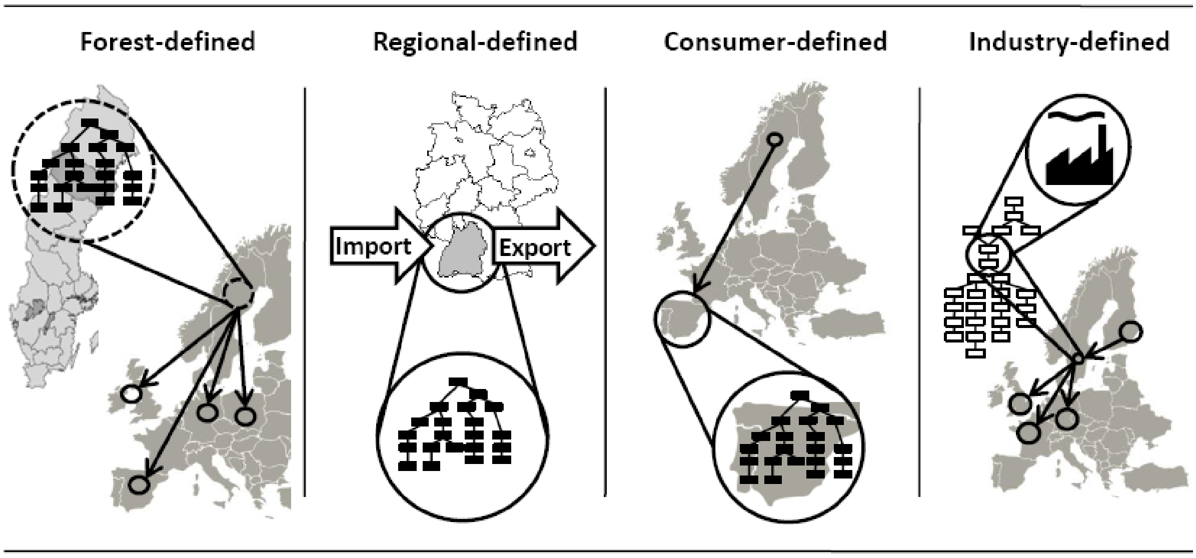


Figure 5. Examples of alternative ways of defining FWCs from the EFORWOOD project

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 are analysed. The industry defined case study is focusing on one or several production facility/ies with specific production capacity, infrastructure etc. Only the processes related to the production facility are analysed.

Depending on definition of the FWC the material flow calculations is initialized in different parts of the chain. E.g. the forest-defined FWC is initialized in the forest management part of the chain. The forest area and the annual harvesting amounts of the defined region (e.g. province, region or continent) are used to initialize the flow calculation.

2.3 Initialization of flow calculations

The initialization is the starting point of the material flow calculation and can happen in different places. Two different types of initialization have to be distinguished, for process (values in process unit – amount of material of the process) or products (in product unit). A EURO based initialization on a product level (value of a product in EURO) would be theoretically possible, however, has not been implemented in the case study applications.

Depending on the perspective, the initialization takes place as follows:

- Forest resource (forest and region-defined), the flow is given by the indicator ***22.1 Forest and Other Wooded Land Area*** (units ha). In addition, imports

are given by the indicator ***3.1.1 Import of wood and products derived from wood – Volume*** (units tons or m^3).
- Consumer initialization (consumer to forest), the material amount is given by the indicator ***99.0 Initialisation.***

The indicator value *22.1 Forest and Other Wooded Land Area* is always entered in ha. As the material flow in the EFORWOOD project is based on statistical data (forest inventory data in BWC and SCS), the data are entered for each forest management process. This provides each forest management process with an initial flow.

Besides the forest area given by the indicator 22.1, other information about the forest as such is needed in order to calculate the material flow (in m3) that originates from the forest resource management process and links with the remainder of the FWC:

- aboveground biomass, m^3 overbark (ob) ha^{-1} (stem wood, tree tops and branches);
- belowground biomass, m^3 ob ha-1 (if also harvested);
- share of total harvested volume of the standing volume.

This information is recorded in the database using the database client in two different places:
- Under “Module specific process attributes” for explanatory purposes, where a potential user can easily see the assumptions made. However, ToSIA does not use this data for its calculations.
- As conversion factors of the output products of the respective processes.

The product shares of the output products indicate, how much of the forest area is harvested. Be aware, that the product shares always refer to the material flow in carbon. Table 1 list the parameter necessary to initialize the ToSIA calculations in the forest management part of the FWC (M2).

Table 1. Parameter essential for the initialization of the ToSIA calculations in M2, all values refer to one year (e.g. 2005)

parameter	explanation
$\boldsymbol{C}$	material flow of process **P** in tons of carbon
$\boldsymbol{M}$	material flow of process **P** in process units (initialization by indicator 22.1)
$\boldsymbol{p_i}$	output product ($i = 1, n$)
$\boldsymbol{s_i}$	product share for output product $\boldsymbol{p_i}$; $\boldsymbol{s_i} \geq 0$; $\sum_1^n \boldsymbol{s_i} \leq 1$
$\boldsymbol{fm}_i$	conversion factor from product units to process units for output product $\boldsymbol{p_i}$
$\boldsymbol{fc}_i$	conversion factor from product units to tons of carbon for output product $\boldsymbol{p_i}$

The internal calculation routine of ToSIA if the initialization takes place in M2 is (see Annex 1 for more details):

In case $\sum_{1}^{n} \boldsymbol{s_i} = 1$ *(all carbon is distributed amongst the output products) the formula is:*

$$\boldsymbol{C} = \frac{\boldsymbol{M}}{\boldsymbol{W}}$$

where:

$$\boldsymbol{W} = \sum_{\boldsymbol{i}=\boldsymbol{1}}^{\boldsymbol{n}} \left(\frac{\boldsymbol{s_i} \times \boldsymbol{fm_i}}{\boldsymbol{fc_i}} \right)$$

Find below an example on how to calculate the input data for ToSIA, when initializing the ToSIA calculation in M2 (indicator 22.1 Forest and Other Wooded Land Area). The provision of such input is usually based on the information obtained from forest inventory/statistic data.

Example:

There is a M2 process "Pine forest" with total area 100 000 ha, so ***M*** *= 100 000 ha (indicator 22.1).*

There are 6 000 ha forest thinned and 4 000 ha are final cuttings, 189 m3/ha are harvested in the thinning and 665 m3/ha in the clear cutting. In absolute numbers we get 1 134 000 m3 by thinning and 2 660 000 m3 in total.

By taking into account wood carbon content 0.219 (tons of C/m^3*) we can calculate the carbon removed; 41.391 tons/ha for thinning and 145.635 tons/ha for clear cutting, (248 346 and 582 540 tons of carbon in total). We can define two output products: thinned trees and felled trees with the unit* m^3*.*

Product	harvest in m^3	harvest in t of C	Product share based on ha
Timber from thinning	1 134 000	248 346	0.06
Timber from clear cutting	2 660 000	582 540	0.04

*The next step is to calculate product shares based on the carbon removal (****s****) for each product. We assume that by harvesting 0.1(sum of product share on ha basis) of total area we get 830886 tons of C (sum of removal). With such assumption we can estimate total potential removed carbon by 830886 tons.*

Hence the input data for the process Pine forest is:

Product	fm	fc	s
Thinned trees	0.005291	0.219	0.029889
Felled trees	0.001504	0.219	0.070111

On the basis of these figures ToSIA will calculate a material flow of 1 134 000 m^3 for the product Timber from thinning and 2 660 000 for the product Timber from clear cutting. A third product e.g. "Forest remaining" could be introduced, but does not necessarily have to.

Data on the belowground biomass is only needed if the stumps are also harvested. This would result in an addition output product in this example. The calculation however, would follow the same procedure as the one presented.

The material flow parameter of the import processes (indicator 3.1) or export processes (indicator 3.2) are entered in tons and m^3. Theoretically, such products could be also initialized by EURO, if the necessary conversion factors are given (e.g. EURO/m3). However, this option has not been applied in these case studies. The indicator expresses the material flow of a product not the processes. The initialization via the indicator 3.2 is only relevant in the consumer defined FWC (e.g. the Iberian Case Study), where the material flow is based on the consumption in a defined region (e.g. paper consumption in the Iberian Case).

2.4 Tracking material flows along the FWC

A FWC is characterized by the material flow entering and leaving each process (Figure XXX). The amount of material flowing through a process in a FWC (as well as process indicator values) is calculated based on the amounts of material that the process being examined receives from processes that precede it in a FWC. The initialisation of the flow calculation provides the starting point for the amount of harvested wood biomass to be used as the basis for deriving all other material flows in the whole FWC being assessed (see section 2.2).

The consecutive calculation of material flows along the FWC uses the information of product output shares and split ratios relative to the input flow of each process, which is also stored in the static information about production processes in the EFORWOOD database.

For each process the input products to a process and their shares (percentage of total input product; in sum 1.0 at maximum), as well as the output products from the process and their specific shares (in sum 1.0 at maximum) are specified. The product shares are process specific (in- and output products) and relate always to the carbon content of the product, not to the mass or volume of the products.

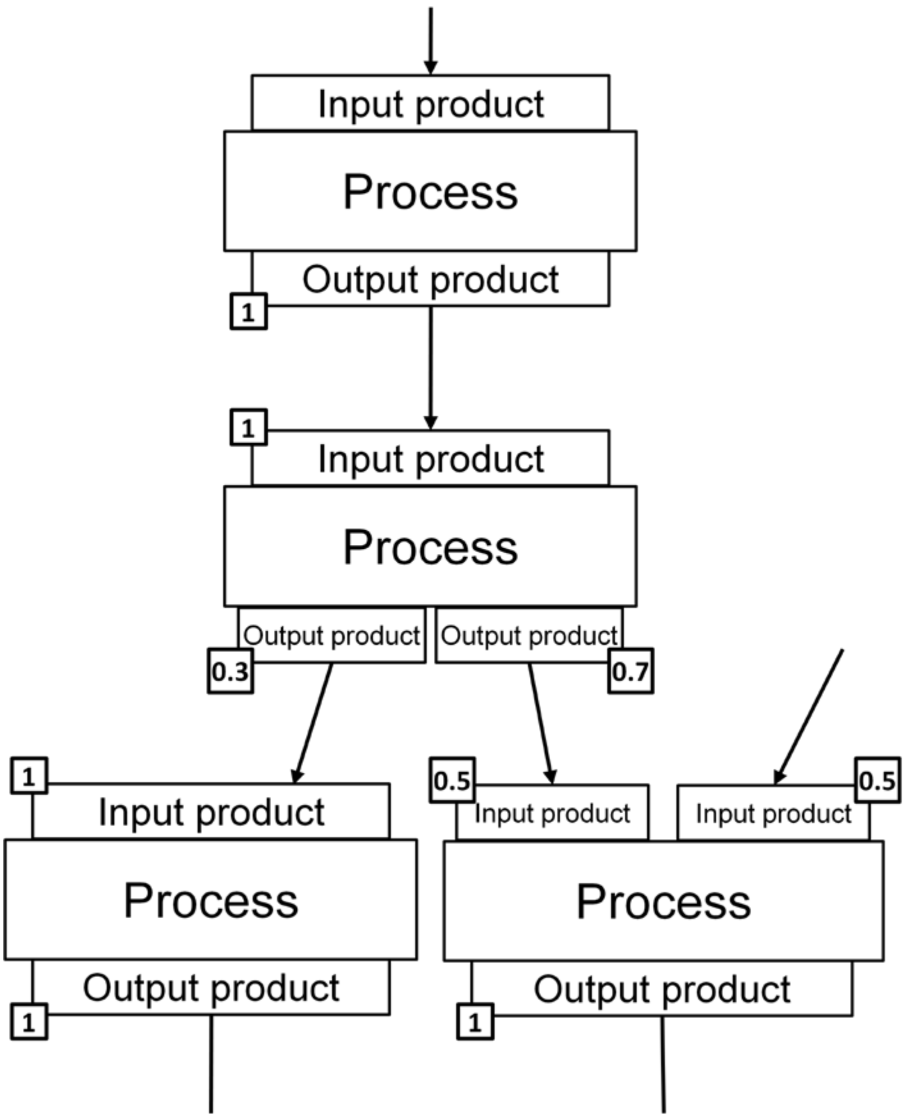


Figure 6. Illustration of the set up of the FWC topology, output products are linked to input products of the successor process, product share (attached to the products) indicate how the material flow is distributed amongst the processes

Furthermore, they always refer to the carbon content of the products and not to the mass or volume. The sum of the product shares should always equal 1. In some exceptions the sum of output share might be <1 if a loss of material flow is simulated e.g. the efficiency losses of energy production in a power plant. However circumstances such as these are better represented by inserting additional products to represent e.g. the efficiency losses. If the sum of the product share exceeds 1, material flow would be incorrectly calculated, resulting in erroneous calculation of indicator results. The single product shares are inserted in the database at the process level for each product.

Split ratios are used to specify links between products (and also processes). They describe how much of the material amount allocated to a product (see product share) is forwarded to the successor process. If a link is created in the database the default value of a link is 1 (i.e. split ratio 1), meaning that the total material amount of a product is forwarded to the succeeding process. There are situations, however, where this assumption is not true e.g. if one product shall be distributed equally amongst 4 processes the sum of the split ratio would equal four (default 1 times 4). Therefore the spilt ratios have to be adjusted in a way that the sum of the single values per link equals one, in the example 0.25 for each link.

Three different types of split ratios have to be distinguished:

- one-to-one (default situation; split ratio = 1);
- one-to-many;
- many-to-one.

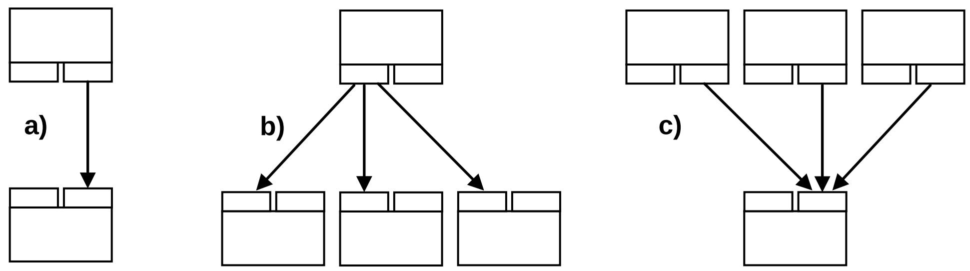


Figure 7. Different types of split ratios: a) one-to-one, b) one-to-many and c) many-to-one

The one-to-many split ratio describes situations where one product (process) is linked to many products (processes).

Another function of the split ratios is to modify the material flow in potential scenarios. The split ratio can be set to any value from zero to one. The material flow is blocked by setting a split ratio to zero as the material flow is always multiplied by the split ratio. The succeeding process does not receive any material flow. If the split ratio is set to one, then all of the material continues from one product (process) to the next product (process). This is also Database Client’s default value when creating a link between two processes.

A more detailed explanation of the calculation of flows can be found in deliverable D1.4.3.

2.5 Linking sustainability indicators to processes

ToSIA provides information on sustainability impacts by calculating environmental, economic, and social sustainability indicators to production processes along the FWC. ToSIA utilizes indicators selected from the framework of sustainability indicators for the FWC, which was developed in 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 data collection in the different case study applications. Data collection protocols have been developed to give clear guidance for the indicator data collection. The latest version of the data collection protocols is accessible for partners via the EFORWOOD portal (www.eforwood.com) under Partners only >> data collection[1]. The final version of the Data Collection Protocol will be documented in Deliverable report PD0.0.16.

All indicators included in the indicator framework have defined measurement units (Indicator measurement unit) and the indicators are reported and stored in the database per unit of material flow (the process 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.

Example
The production cost indicator (subclass labour cost) is calculated for the process of transportation of pellets for home-scale use:

- process 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 process unit which is the same for all indicators (i.e. in our example above tons of pellets), as indicator values are always linked to a specific process and therefore collected per process unit of this particular process.

The indicators may be reported with different process units (in the previous example tons for pellets or m3 for saw logs) – this is especially the case for modules 3-5. Therefore, conversion factors are required to convert the process units in the database to the reference unit for the modules "tons of C content" and vice versa. For each individual product occuring in the FWC a conversion factor is required.

The indicator values per material flow (e.g. labour cost of the transport of pellets is 2.7 €/tonne of pellets) were delivered to the EFORWOOD database by project partners in modules 2-5. In most cases they are derived from available statistical data sources or they are generated from outputs of process-specific models or other data available to modules 2-5. Expert judgements can be used, where other more robust data is lacking. In any case, the indicator values reflect the best available knowledge about the sustainability of the processes included in the selected FWCs (see also 3.2 data verification).

2.6 Calculating sustainability indicator values of the FWC

Each process has a group of indicators expressed with a **relative indicator value** (material flow is here expressed in process unit). The indicator values per unit of material flow are process-specific. In ToSIA, sustainability indicators are linked to the total input material amount of a process. Absolute sustainability indicator values for a process are calculated by multiplying the total input material amount of a process with each of the process' relative indicator values. This result is called a **calculated indicator result** (Figure 8)**.**

[1] http://87.192.2.62/eforwood/Partnersonly/Datacollection/tabid/229/Default.aspx (only partner have access)

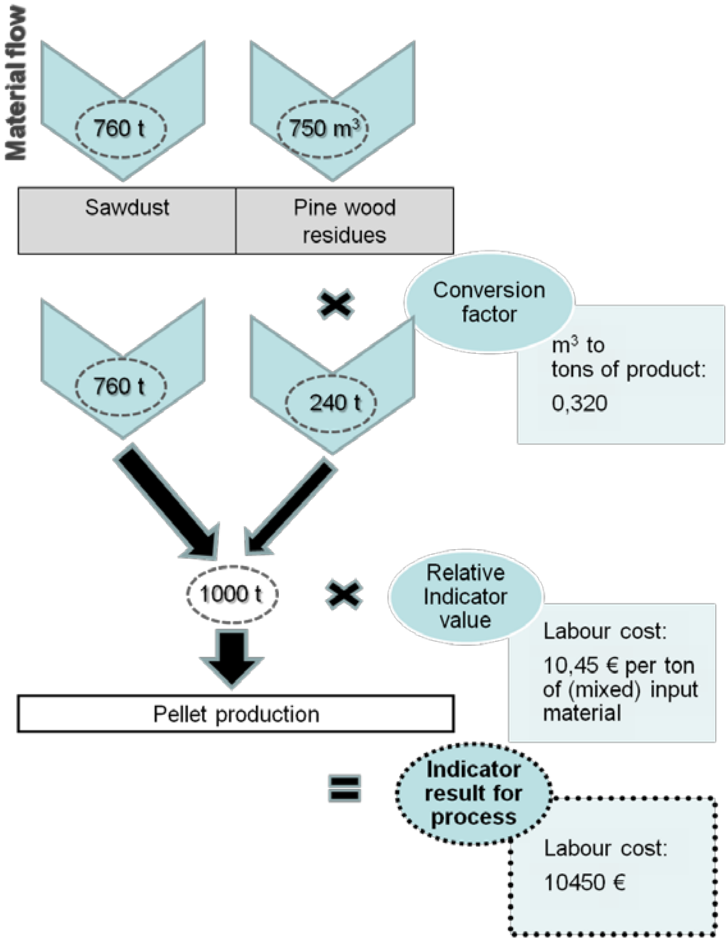


Figure 8. Calculation example for the labour cost indicator in the pellet production process. Indicator data are reported relative to the process unit of the process (tons). As needed, ToSIA converts each incoming material flow to process unit using products-specific conversion factors, and multiplies the total sum amount of incoming material with a relative indicator value to get the calculated indicator result per process.

After computing the calculated process indicator values with the total material flows for each process, ToSIA also aggregates them along the FWC by module and chain. 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, e.g. share of female employment, are aggregated by their weighted average instead of sum. In this current version of ToSIA, the aggregation method was individually specified for each single indicator and sub-indicator.

In the SIA it is possible for some indicator subclasses to be aggregated together. For example, the total *Occupational accidents* are the sum of the sub-indicator *Occupational accidents (non-fatal*) and *Occupational accidents (fatal)*. As long as the units of the indicators are compatible, the aggregation of the indicators is straightforward.

The calculated indicator results are presented in ToSIA as a table by process or aggregated by module. The results can also be displayed as a pie or bar chart. Results of different FWC can be compared.

2.7 Processing and saving of result

All ToSIA results are automatically exported in a CSV format to the same directory as the program when saving a ToSIA run. The result files carry the name ([...]) as specified by the user in the GUI followed by a postfix. Table 2 lists all ToSIA result files, which are exported from the tool.

Results	Automatic naming by ToSIA	Comment
Indicator results	[...]_tosia_indicator_results.csv	Indicator results are listed per process, aggregated by module and chain
Material flow	[...]_tosia_calculated_product_flows.csv	Material flow listed by linked output and input products, i.e. product not linked are not listed
Material flow	[...]_tosia_calculated_flows.csv	Total input material flow of process (sum of input products)

Table 2. ToSIA output results files, in bracket the name of the run given by the user, the postfix is automatically given by ToSIA

2.8 Analysis tools for indicator results

The calculated and aggregated ToSIA indicator results themselves do not provide an answer to the question of how a change (e.g. a political decision) affects the overall sustainability of a FWC. However, changes of indicator values in percent between different chain variants can be compared, i.e.

(i) relative indicator results per product unit produced (e.g. m^3 harvested), or
(ii) absolute indicator results FWC alternatives.

The interpretation of the sustainability of the different results needs to be done with the help of evaluation methods. In the EFORWOOD project, three different evaluation methods were selected: Multi-Criteria Analysis (MCA), Cost–Benefit Analysis (CBA) and Policy Analysis (PA).

The main exercise behind the MCA and CBA is to transfer the original indicator value onto a common scale of preference. It is this common scale that eventually allows indicators to be aggregated by summing up the dimensionless preference values a decision maker or a stakeholder assigns to them (i.e. the comparison of “apples and pears”).

MCA can be viewed as an approach as well as a framework of techniques designed to help people make decisions which are in accordance with their values when faced by multiple, non commensurate and conflicting criteria (See Deliverable Report D1.5.7). MCA can assist in transforming the rather broad sustainability concept into something operational and practical. Sustainability Impact Assessment (SIA), despite its inherent complexity, can be formalised and conducted systematically because MCA has proved to be an effective tool for selecting, evaluating and aggregating the various indicators of forest sustainability. MCA is already incorporated in the current version of ToSIA.

In EFORWOOD, CBA was applied to analyse the differences between e.g. two optional FWCs which a decision maker may generate through two different policies (See Deliverable Reports D1.5.6). The CBA is performed from a social perspective, i.e. 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, SOx'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.
The task of the Policy Analysis (PA) section was to develop a systematic framework of institutional indicators and a related data-base of current relevant policies as well as a PA component for ToSIA baseline and scenario runs (cf. Deliverable report D1.1.5 and PD1.1.9). The data-base of current EU and supranational policies contains policies that are deemed to have an effect on sustainability indicators in the FWC and compile thresholds identified by scientists and set by these policies. This policy data-base covers all policy areas (biodiversity, trade, forest, climate, and environment), sector-specific policies, and specifications of FWCs (relevant products and production specifications, energy, transport) that are of key relevance to the sustainability performance of the FWC. Existing thresholds for the indicators as specified through legislation or international commitments will be identified through a detailed review and screening of existing EU and international policies. However, the PA component for ToSIA results is still under development.

3 Technical implementation of the ToSIA version 1

In this section only a brief introduction to the ToSIA version 1 is given.

In the version of ToSIA 1.0, a graphical user interface has been developed as well as the implementation of the functionality to compare alternative chains and scenarios. Further, the calculation of different time steps and scenarios (variants) was implemented. In a next major step the calculation of the EU FWC was implemented. For the calculations ToSIA receives its input data from the EFORWOOD database. Since the last ToSIA version (prototype 2) more information is given to the user about the results of the flow calculation. Furthermore, the presentation of the result has been improved. The user has the possibility to choose between a table, bar or pie chart. The aggregated indicator results of the selected variants can be compared in ToSIA. When saving a run ToSIA automatically exports the results as CSV file.

The basic steps followed by ToSIA to make the calculation of the sustainability indicators are shown in Table 3.

Table 3. Basic steps followed by ToSIA version 1.0 to make sustainability calculation, a more detailed instructions on the use of ToSIA can be found in deliverable D1.4.10

The ToSIA sustainability calculation proceeds as follows: 1. First the data is generated/downloaded from the Database Client via two xml-files: the chain file and the process file. The user has to select the wanted chains available in the database. 2. The data is loaded into ToSIA. First the chain xml is loaded. This file defines the topology of the chains. It also carries the information on the split ratios. 3. Then the process file is loaded. The process xml-file contains all information linked to a process: all indicator values, conversion factors, product shares, definitions, etc. 4. Once the structures of the FWCs are established, the material flows along the FWC are calculated using the initialisation flows. Conversion factors, split ratios and product shares are requested in this phase. The material flow is converted into the process units for each process respectively. 5. Next the indicator results are computed for all processes by multiplying the material flow per process with the relative indicator values. 6. The indicator results per processes are aggregated along the chain with arithmetic operations. The aggregation method (i.e. summing or averaging) depends on the indicator type. 7. The calculated indicator results are shown in ToSIA as tables or different graphs depending on the user's choice. In addition the indicator results as well as the material flows are exported from ToSIA as csv–files in the same directory as the tool is stored.

ToSIA version 1.0 is now implemented to handle the specified Case Study Chains; to realize the calculation of the complex and data-intensive European FWCwas a more advanced step and a main outcome of the EFORWOOD project, as it proves that ToSIA is capable of handling also large-scale studies with intertwined trade flows. During the prototyping phase the specification of the model and the data to be analysed has been refined. The model has evolved and changed along the timeline of ToSIA developments. The final version of ToSIA is 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.

4 Data verification

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 9). For a detailed report on the data validations efforts taken in the project please see D.1.2.6 *Data quality*.
The data is introduced into the database from various sources (statistics, research data, modelling outputs etc.) using 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 a complete and consistent set of the conversion factors.

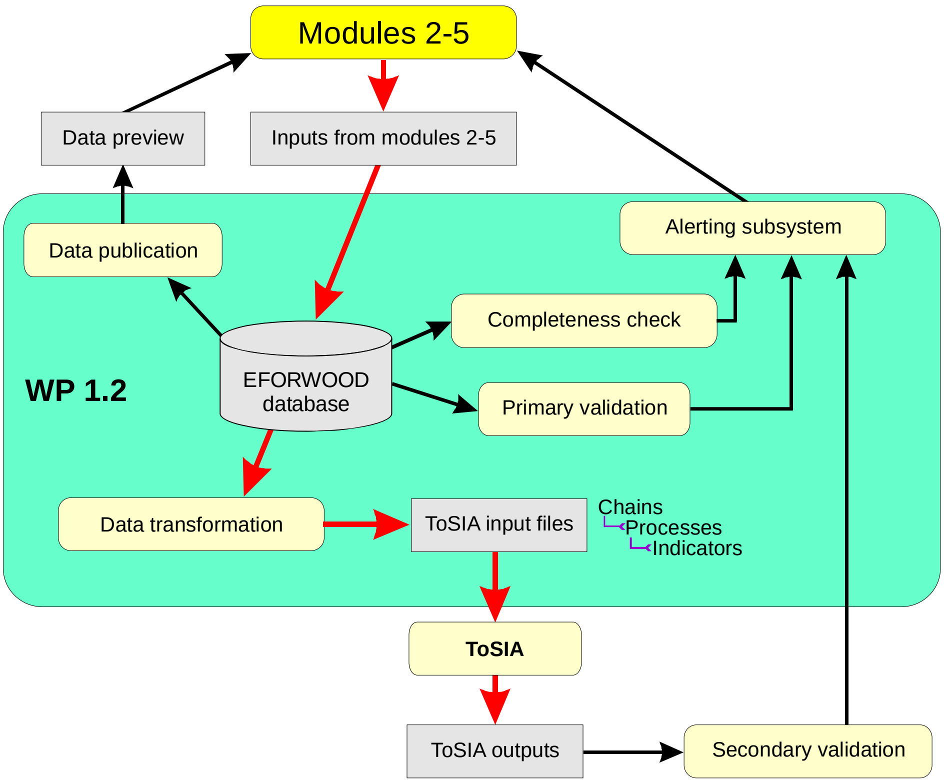


Figure 9. The EFORWOOD database collects the information from the project modules 2-5 and provides the necessary input data to run ToSIA. Data quality checks are done in several steps to secure the best possible output quality of the ToSIA results. The first data check is performed when data are submitted to the database. Both completeness of the data and individual values are checked.

Routines have being developed to check automatically inconsistencies in the reported data. Some of these routines are integrated into ToSIA, e.g. the ToSIA data report (chapter 4.3). 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. Fundamental errors in the topology of the FWC, (e.g. processes which are not correctly linked) make ToSIA crash. An error message indicates the reason for the error.

ToSIA independent calculation routines were developed to validate the indicator data and conversion factors. They are introduced in chapter 4.1 and 4.2. To make the calculation as transparent as possible (black box) as well as for validation purposes, ToSIA exports relevant input data, i.e. relative indicator values (as inserted in the database), output product shares and split ratios (see 4.3). Furthermore, the ToSIA internal testing routine (ToSIA Data report) is introduced.

4.1 Conversion factors

Conversion factors are a crucial part of correct calculation of the material flows (excluding the conversion factor to EURO as it is not needed for the material flow calculation). As we are dealing with wood products, two variables largely determine the conversion factors: (i) the physical wood properties of the tree species or product (e.g. paper) and (ii) the moisture content. Each tree species harvested in the different case studies has a specific dry weight. A general approximation in the EFORWOOD project was that 50% of the dry weight is carbon. Furthermore, the moisture content of the wood decreases from the harvesting processes until the use stage of the wood product.
On the basis of those assumptions constraints were developed, to verify conversion factor inserted in the data base and used in the material flow calculations.

Assumptions:

- 0.5 of the dry weight of the timber is carbon
- the weight in tons of 1 m3 oven-dry wood product is twice the conversion factor (cf) to tons of C
- the conversion between the same units is always 1

Calculation of moisture content

- weight of the product minus the dry weight (twice the carbon content) divided by the dry weight of the product multiplied by 100, equals the moisture content of the product in %

4.2 Indicator values

For the data for the single chains it was possible to validate the data manually. Because of the enormous amount of data for the three regional case studies (BWC, SCS, ICS) and the EU FWC, manual validation was not efficient. An automated test of indicator values was carried out by vTI.

The evaluation of indicator data was split into two parts:

1. a check of constraints of indicator values within one process;
2. a check of outliers of indicator values in relation to a group of processes.

Based on the logic of the indicator and/or sub-indicator structure or expert guesses constraints for indicators or sub-indicators within one process have been defined.

The constraints lead to specific thresholds for indicators or to expected values that should be matched.

In order to be able to identify outliers of indicator values the processes of the case studies and the EU case were stratified by logical context. Within one process group the mean values of the respective indicator values were calculated. Subsequently, minimum and maximum thresholds were defined. The minimum threshold has been set at 10% of the calculated average, the maximum threshold as five times (500%) the average. All indicator values which were not within this range were defined as outliers.

The results of the testing of indicator values against constraints and outliers were listed in separate Excel files and sent to the responsible partners in order to correct them if necessary and confirm the corrections by email.

4.3 Exporting of indicator values, output product shares and split ratios from ToSIA

To make the loading and calculation procedure of ToSIA as transparent as possible, the share of the output product, the split ratios (many to one) and the relative indicator values (per unit of material flow) are exported from ToSIA. The files on the split ratios and the output product shares are saved in the same directory as the program as soon as the data was loaded. Furthermore they are generated only once for all variants, whereas the relative indicator values are generated only if the run is saved. The indicator values are stored in the same file with the calculated indicator results. The files are all generated in a CSV file format and can be imported into Excel. The delimiter of the files is either the hash sign (“#”) or a comma (,) (see Table 4). In addition the files can be used to detect errors in the data.

Table 4. Files exported from ToSIA

File	Automatic naming	Delimiter
Output product share	(name of FWC)_tosia_output_shares.csv	#
Split ratios	(name of FWC) _tosia_output_split_ratios.csv	#
Relative indicator values	(name given saving run)_tosia_indicator_results.csv	comma

4.4 ToSIA data report

The validation of the figures needed for the flow calculations was done with the help of ToSIA. Several testing routines were implemented. All errors or deviations of the established routines are reported in the ToSIA data report. This report has the following different testing routines:

- Missing conversion factors

Whenever a needed conversion factor is missing, it will be reported. This accounts for the conversion factors from product unit to tons of carbon and from product unit to process unit if the units differ. In order to make ToSIA calculate flows even if those essential values are missing, a default functionality was introduced which sets missing indicator values automatically to zero.

- Missing split ratios
  If a split ratio (one-to-many) has not been entered, the sum of the default value always exceeds one (see also 2) and is included in the data report. Whenever the sum of the split ratios ≠ 1 it is reported.
- Sum of the split ratios ≠ 1
  Whenever the sum of the split ratios ≠ 1 it is included in the data report.
- Sum of the product shares ≠ 1
  Whenever the sum of the product shares of a process is ≠ 1 a report is written. In some cases it is possible for the sum of the product shares to be less than one – e.g. if some process waste (such as dust emissions) is unaccounted for.

Furthermore the results of another test are stated in this report, which is a combination of the testing routines above. This particular report indicates whenever the relative output flow of a process differs from one. This should be seen as additional information on the material flow calculations. In some cases the messages indicate errors in the data – e.g. if split ratios have not been correctly entered into the database then the results may show that 100% of a product is distributed to each of several succeeding processes (one-to-many – 1 to 5 processes -> 500%), resulting in an incorrect multiplication of the amount of that product. In some cases the messages indicate certain situations that can really occur in the chains – e.g. one output product (waste) is not continuing in the chain.
Therefore, the messages in the ToSIA data reports require interpretation by the ToSIA users.

The ToSIA data report is displayed in ToSIA (data verification). In addition the report is generated and automatically saved as a CSV file in the same directory in which ToSIA is stored.

The delimiter of the CSV file is the hash sign (#). The report is structured after the time validity (scenario), process name and ID, the name of the contact person (data provider) and last but not least the report itself. This information proved to be sufficient to find the error in the data set.

5 Introduction to case studies and data results

5.1 Specification of Case Studies

In the EFORWOOD project three different case studies were developed, each with a different geographical focus and specific research questions to be answered. The material flow calculation was initialized in different ways as for example, in the consumer driven Iberian Case Study (ICS) or the resource driven Scandinavian Case Study (SCS) (see 2.2), or the scope of the study can be limited to the forest sector of a region as it was done in the Baden-Württemberg Case Study (BWC). The Case studies are composed of several, partly interlinked internal FWCs (the level of aggregation might differ from the single FWCs).

Each case study is set up with different variants: baseline 2005, reference futures A1 and B2 for 2015/2025, and on top of the two A1 variants a case study specific scenario (cf. D1.4.7). The 2005 baseline represents the current status. The reference futures A1 and B2 are two global storylines based on projections how the world could develop:

A1. A world with rapid economic development (i.e. stronger role of India, china, etc), high level of technological innovation, and convergence between world regions.

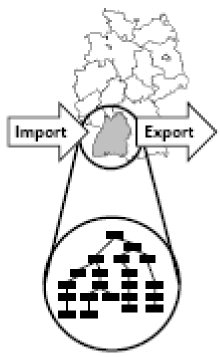
B2. The emphasis is to local solutions to economic social and environmental challenges. Less rapid economic growth, with global regions being independent. A scenario with more diverse technological change, and more emphasis on environmental protection.

The scenario alternatives focus on particular developments of each case study, e.g. the BWC was focusing on an increasing demand of woody biomass for energy products, where as the SCS dealt with technologies developments in the forest industry. For all the variants 2015 and 2025 were selected as suitable time steps.

In the next chapters different case studies are presented.

5.1.1 Baden-Württemberg Case Study

The BWC area represents the Central-European region characterised by mixed hardwood and softwood forests and a highly diversified wood industry. The FWC is regional defined and aims to describe the network of forestry-wood chains in Baden-Württemberg including imports into the region and exports out of the region and cross-links between the different production lines of sawmilling, pulp & paper and the bioenergy sector. A more detailed documentation can be found on the EFORWOOD portal (www.eforwood. org) under the section "ToSIA » Case Studies » Baden Württemberg Case".



For this case study only the tree species Norway spruce (*Picea abie*s (L.) Karst.) and European beech (*Fagus sylvatica L.)* were considered as these two species account for more than two-thirds of wood volume produced in Baden-Württemberg. The main wood industry sectors sawmilling, pulp and paper production, panel production, bio-energy and successional industries are present in Baden-Württemberg, and were therefore taken into account and included in the case study. As there are no official statistics for consumption of wooden goods and wood based products for Baden-Württemberg, the following approach was taken to estimate the consumption of goods from statistical data for Germany broken down per capita for Baden-Württemberg. Material import and export into and out of Baden-Württemberg occurs for roundwood, semi-finished products and end-products, but imports and exports from the other 16 federal states in Germany cannot be quantified; also European and overseas imports and exports can only quantified on an overall German basis. To overcome this problem, volumes of material in exports and imports in each category was handled as net-balance. The volume of material was derived from known volumes produced in Baden-Württemberg and known volumes consumed. From that difference either an import or an export of wood volume in this category was assumed without differentiation wherefrom or whereto the material comes unless this is known by expert knowledge. Altogether 60-80% of the natural production in the forests, of primary and secondary processing in the wood industry, i.e. wooden products, paper and boards, panels and bio-energy, and of the consumption of the produced goods were covered in the case study. Disposed products after consumption were either incinerated or recycled as a feed-back into the material flow.

In the BWC 153 processes and 73 products were defined. In the indicator demonstration set 85 indicators and sub-indicators were selected. Furthermore seven variants were developed: 2005, 2015 A1, 2015 B2, 2025 A1, 2025 B2, 2015 A1 bioenergy and 2025 B2 bioenergy. The details and assumptions of the reference futures and scenarios for the BW case study are described in detail in the deliverable "PD3.0.3: Definition of Case-study "Baden-Württemberg" – Update July 2008". The bioenergy scenarios describe an increased utilization of bio-energy from the forest (e.g. Harvest residues, stumps, and industrial wood), the industry (sawdust, chips, bark, black liquor, rejects and downgraded assortments) and the consumptions (bio fuel in harvesting, forwarding and transport). If you would multiply the number of processes by the number of indicators by the number of variants you would get the theoretical number of single values collected in the BWC (91 035 values). However not all indicators are applicable for each process (e.g. water use of forest ecosystem in harvesting processes) and sometimes data collection was not feasible[2]. Around 36 000 single indicator values were entered into the database. The numerous conversion factors, input and output product shares and split ratios are not included in this number.

The data completeness was reported and discussed in D1.2.5 and D1.2.6.

[2] Not feasible: no meanigful data was found, no statistical data was available and expert guess was not feasible

The conversion factors in the BWC were based on the assumptions shown in Table 5. Only the commercially utilized tree species beech and spruce where taken into consideration in this case study.

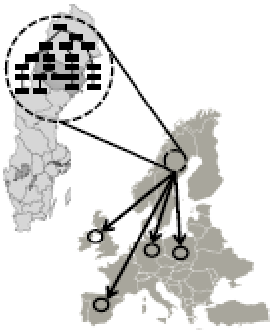
Table 5. Basic assumptions for the calculation of the different conversion factors

name Product	unit	conversion	value	mc in %
fiber products	tons	Product unit to tons of C	0.5	0
Spruce log	m3	Product unit to tons of C	0.21025	-
Beech log	m3	Product unit to tons of C	0.309845	-
Dry weight of spruce	m3	Product unit to tons	0.4205	0
Dry weight of beech	m3	Product unit to tons	0.619691	0
Spruce fresh	m3	Product unit to tons	0.79	88
Beech fresh	m3	Product unit to tons	1.025	65

5.1.2 Scandinavian Case Study

The Scandinavian Case Study (SCS) is forest-defined and aims to describe the network of the forestry-wood chains which originate from forest resources in Västerbotten, Sweden including production and consumption of wood products outside of the region in other parts of Europe. A more detailed documentation can be found on the EFORWOOD portal (www.eforwood.org) under the section "ToSIA » Case Studies » Scandinavian Case".

The case study "Scandinavian production case" is chosen to represent the boreal European FWC whichare characterised by large scale silvicultural management and stands dominated by Scots pine (*Pinus sylvestris L.*) or Norway spruce (*Picea abies (L.) Karst*.) or of mixtures of the two species with or without broadleaved species (most commonly birch, *Betula spp*.). The stands in the region are mainly even-aged and the dominating harvesting techniques include the highest technology available at present, i.e. harvesters and forwarders. The dominating transport from the forests to industry includes road transport with 60 ton trucks. The main wood industry products include saw logs, pulpwood and fuel wood of pine, spruce and birch, forest wood chips, and stumps. The main industries are sawmills, Kraft pulp mill, fine paper mill and combined heat and power (CHP) plants. The produced goods from the FWC in Västerbotten consist of e.g. edge glued panels, wood furniture, pellets and bioenergy.



In the SCS 158 process and 55 products were defined. For the demonstration indicator set 68 indicators and sub-indicators were selected. Similar to the variants in the BWC, five different time steps and reference futures were selected; however, the focus in the SCS lies on technology development. Hence two technology scenarios were defined: 2015 A1 technology and 2025 A1 technology. The theoretical number of indicator values to be collected is 60 830. Indicators which are not applicable for various processes or which could not be collected due to a lack of data (not feasible) have to be subtracted from this number. The sum of indicator values inserted in the database for this case study is 31 708. The numerous conversion factors, input and output product shares and split ratios are not included in this number. The data completeness was reported and discussed in D1.2.5 and D1.2.6.

The conversion factors in the SCS were based on the assumptions shown in table 6. Only the tree species pine and birch where taken into consideration in this case study.

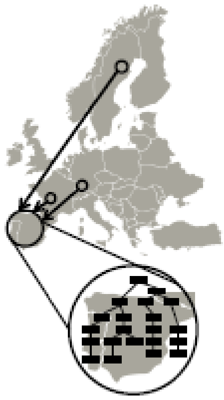
Table 6. Basic assumptions for the calculation of the different conversion factors

name Product	unit	conversion	value	mc in %
Fiber products	tons	Product unit to tons of C	0.5	0
Pine log	m3	Product unit to tons of C	0.2107	-
Birch log	m3	Product unit to tons of C	0.250833	-
Dry weight of pine	m3	Product unit to tons	0.4214	0
Dry weight of birch	m3	Product unit to tons	0.501666	0
Pine fresh	m3	Product unit to tons	0.815	93
Birch fresh	m3	Product unit to tons	0.97	93

5.1.3 Iberian Case Study

The Iberian case study (ICS) analyses FWCs which are producing wood products that are consumed in the Iberian Peninsula. The ICS serves the purpose of testing the implementation of a consumption-defined case study in ToSIA. The approach is market driven with main focus on changes in consumption of final products. A more detailed documentation can be found on the EFORWOOD portal (www.eforwood.org) under the section “ToSIA » Case Studies Iberian Case”.

The implementation of this case study required backward tracing of material flows which are needed to grow and manufacture the resources needed for the consumption of selected final products in Iberia. This proved to be quite a challenging task, as data on product markets are very heterogeneous and the supplying value chains are not easy to identify. The ICS focuses on fibre products (paper, magazines and packaging material). Solid wood products were excluded as data availability was insufficient. For pragmatic reasons, it was decided in EFORWOOD to utilize part of the existing FWC information from other case studies to characterise the supply chains of Iberian wood products.



Among the three case studies of the EFORWOOD project, the ICS is the smallest case study in regards to the number of processes and products defined. Only 82 process and 150 products were defined. For the demonstration indicator set 65 indicators and sub-indicators were selected. Similar to the variants in the other case studies five different time steps and reference futures were selected, however, the focus in the ICS lies on changes of the consumption. Hence two technology scenarios were defined: 2015 A1 and 2025 A1 consumption scenario. The theoretical number of indicator values to be collected 37 310. The actual number of indicator values inserted in the database (i.e. not including indicators which are not applicable for various processes or which could not be collected due to a lack of data) for this case study is 18 239 (excluding conversion factors, input and output product shares and split ratios). The data completeness was reported and discussed in D1.2.5 and D1.2.6.

The conversion factors in the ICS were based on the assumptions shown in Table 7. In this case study tree different tree species were taken into consideration eucalypt, maritime pine and birch.

Table 7. Basic assumptions for the calculation of the different conversion factors

name Product	unit	conversion	value	mc in %
Fiber products	tons	Product unit to tons of C	0.5	0
Pine log	m3	Product unit to tons of C	0.2107	-
Eucalypt log	m3	Product unit to tons of C	0.2251	-
Birch, spruce, pine Scandinavia	m3	Product unit to tons of C	0.250833	-

Dry weight of Maritime Pine	m3	Product unit to tons	0.4214	0
Dry weight of Eucalypt	m3	Product unit to tons	0.4502	0
Dry weight of Birch, spruce, pine Scandinavia	m3	Product unit to tons	0.501666	0
Maritime pine fresh	m3	Product unit to tons	0.815	93
Scandinavian pine fresh	m3	Product unit to tons	0.97	93
Eucalypt fresh	m3	Product unit to tons	0.584	30

6 Discussion

EFORWOOD WP 1.4 developed the ToSIA tool framework, tested the tool and calculated sustainability indicators for current and future alternative FWCs at regional and European levels. Objectives of the WP were 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, and to develop, test, and apply ToSIA for different applications in EFORWOOD. The WP was also responsible for coordinating the development and specification of commonly agreed scenarios. Those commonly aggreed specifications and assumptions are described in a common format in "D 1.4.7. Reference futures and Scenarios for the European FWC", including quantified drivers under A1 and B2. The specific assumptions vary according to the scenario and the connected cse study. These result in effects those scenarios have in terms of their indicators of current and alternative FWCs, which were simulated in the EFORWOOD case studies at the regional and continental scale taking into account internal and external drivers. These drivers and impacts are described in the context of the case study documentation updates, and specific scenario documentation. For simplification purposes each scenario was "started" in a certain module and the impacts of these scenario assumptions in that module spread to the connected and follow-up modules.
These are:

- *Baden-Württemberg Case study*, Module 3 assumptions:
  PD3.4.5 Development and selection of M3-specific key scenarios for ToSIA at case study level
- *Scandinavian case study*, M4 assumptions:
  PD4.1.10 Report describing the technology scenario
- *Iberian case study*, M5 assumptions:
  Descriptions of the Consumption Scenario for Iberia - newspaper
- *EU FWC study*, M2 assumptions:
  Schelhaas, M.J., Didion, M., Hengeveld, G., Nabuurs, G.J., Mason, B., Lindner, M., Moiseyev, A., Edwards, D. in prep. Impact of different levels of nature conservation designation on European forest resources. To be submitted to Ecology and Society

ToSIA prototype 1 proved the concept of dynamic flow calculation for the material flows along the chain, though the flows were calculated only using the initialization flow information at the M2/M3 boundary. ToSIA prototype 2 gave more information to the user about the results of flow calculation and presented 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 handled in a generic way.

Case study FWCs described above in Chapter 5 were created to demonstrate, test and develop the ToSIA software. Tests showed that ToSIA produces meaningful results and that the approach is reasonable. The case studies also provided 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: – Process units should be consistent for each process – Indicator measurement units needs to be consistent along the chain to make it possible to	- 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

	aggregate the values

With the case studies it was demonstrated that ToSIA is able to calculate material flows along FWCs, and calculate and assess indicator values (economic, social and environmental) for processes along the FWCs. Loop chain calculation was implemented in recycling loops.

The presentation of sustainability indicator results in this report includes the scope of the case studies within their specified system boundaries. With ToSIA it is possible to compare alternative management practises within the same chain and their effects on the indicators. With this it is possible to assess chain variants, such as reference futures and scenarios for each case study.

An important question is how to verify the results in the future? Different approaches and tools have been developed for that purpose, but there is still room for improvement. First of all, the database client has already proved to be useful in data collection and browsing. It would benefit from visualisation of the contained data, in order to help identify mistakes and misunderstandings in data collection. ToSIA itself includes different methods for checking the data quality and completeness; these are displayed under “ToSIA data reports” within ToSIA itself (Data preparation tab). The reliability of the ToSIA results completely depend on the data provided to ToSIA.

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ANNEX 1 Initialization of ToSIA calculations in process

The following explains the relations between the material flow given in process units and the tons of carbon for a process in a FWC. This algorithm is used by ToSIA only in cases were an initial value (material flow in process units) for a process is given and the initial carbon flow has to be calculated. For example, the initialization of a forest management process in ha by the indicator 22.1.

Table XXX: Parameter essential for the initialization of the ToSIA calculations in M2

parameter	explanation
$\boldsymbol{C}$	amount of flow for process **P** in tons of carbon
$\boldsymbol{M}$	amount of flow for process **P** in process units
$\boldsymbol{p_i}$	output product $(i = 1, n)$
$\boldsymbol{s_i}$	share of carbon for output product $\boldsymbol{p_i}$; $\boldsymbol{s_i} \geq 0$; $\sum_1^n \boldsymbol{s_i} \leq 1$
$\boldsymbol{fm_i}$	conversion factor from product units to process units for output product $\boldsymbol{p_i}$
$\boldsymbol{fc_i}$	conversion factor from product units to tons of carbon for output product $\boldsymbol{p_i}$

Then amount of carbon flow for product $\boldsymbol{p_i}$:

$$\boldsymbol{c_i} = \boldsymbol{s_i} \times \boldsymbol{C}$$

amount of flow in process unit for product $\boldsymbol{p_i}$:

$$\boldsymbol{m_i} = \frac{\boldsymbol{c_i} \times \boldsymbol{fm_i}}{\boldsymbol{fc_i}}$$

$$\boldsymbol{m_i} = \frac{\boldsymbol{s_i} \times \boldsymbol{fm_i}}{\boldsymbol{fc_i}} \times \boldsymbol{C}$$

With the assumption, that the relation between carbon and mass is linear for a given process, we have:

$$\boldsymbol{M} = \frac{\boldsymbol{1}}{\sum_1^n \boldsymbol{s_i}} \times \sum_{i=1}^{n} \boldsymbol{m_i}$$

$$\boldsymbol{M} = \frac{\boldsymbol{1}}{\sum_1^n \boldsymbol{s_i}} \times \sum_{i=1}^{n} \left(\frac{\boldsymbol{s_i} \times \boldsymbol{fm_i}}{\boldsymbol{fc_i}} \times \boldsymbol{C} \right) = \frac{\boldsymbol{1}}{\sum_1^n \boldsymbol{s_i}} \times \boldsymbol{C} \times \sum_{i=1}^{n} \left(\frac{\boldsymbol{s_i} \times \boldsymbol{fm_i}}{\boldsymbol{fc_i}} \right)$$

Thus, the relation between carbon and mass follows the equation:

$$\boldsymbol{M} = \frac{\boldsymbol{1}}{\sum_{\boldsymbol{1}}^{\boldsymbol{n}} \boldsymbol{s_i}} \times \boldsymbol{C} \times \boldsymbol{W}$$

Or (solving for C):

$$\boldsymbol{C} = \frac{\boldsymbol{M}}{\boldsymbol{W}} \times \sum_{\boldsymbol{1}}^{\boldsymbol{n}} \boldsymbol{s_i}$$

where:

$$\boldsymbol{W} = \sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \left(\frac{\boldsymbol{s_i} \times \boldsymbol{fm_i}}{\boldsymbol{fc_i}} \right)$$

In case $\sum_{1}^{n} \boldsymbol{s_i} = 1$ (all carbon is distributed amongst the output products) the formula is:

$$\boldsymbol{M} = \boldsymbol{C} \times \boldsymbol{W}$$

or:

$$\boldsymbol{C} = \frac{\boldsymbol{M}}{\boldsymbol{W}}$$

ANNEX 2 Indicator demonstration set

Legend:
- Y — indicator selected for demonstration set
- T — calculated by ToSIA
- Blank — not selected for demonstration indicator set

Name	BWC	SCS	IBC
1.1 - Gross value added (at factor cost)	Y	Y	Y
2.1 - Production cost	Y	Y	Y
2.1.1 - Average cost - raw materials from FWC	Y	Y	Y
2.1.2 - Average cost - raw materials from outside FWC	Y	Y	Y
2.1.3 - Average cost - labour costs	Y	Y	Y
2.1.4 - Average cost - energy costs	Y	Y	Y
2.1.5 - Other productive costs	Y	Y	Y
2.1.6 - Non-productive costs	Y	Y	Y
4.1.2 - Other renewable materials in total	T	T	T
4.1.2.1 - Other renewable materials - virgin origin	T	T	T
4.1.2.2 - Other renewable materials - recycled origin	T	T	T
6.1 - Investment (gross fixed capital formation) in total		Y	
6.1.1 - machinery and equipment		Y	
6.1.2 - vehicles		Y	
10.1 - Employment - absolute number	Y	Y	Y
11.1 - Wages and salaries - total	Y	Y	Y
11.2.1 - Average wages & salaries per employee relative to country average	T	T	T
11.2.2 - Average wages & salaries per employee weighted by purchasing power parity	T	T	T
12.1 - Occupational accidents - total	Y	Y	Y
12.1.1 - Occupational accidents (non-fatal) - absolute numbers	Y	Y	Y
12.1.2 - Occupational accidents (fatal) - absolute numbers	Y	Y	Y
15.1 - Persons employed part-time and employees with a contract of limited duration (annual average) in total	Y		
15.1.1 - Persons employed part-time and employees with a contract of limited duration (annual average) - male	Y		
15.1.2 - Persons employed part-time and employees with a contract of limited duration (annual average) - female	Y		
15.2 - Self-employed persons	Y		
16.1.1 Forest area designated for recreational use	Y		
17.1. - Apparent consumption of wood per capita			Y
18.1 - On-site energy generation from renewables	Y	Y	Y
18.1.1.1 - On-site heat generation from renewables - residues from process - inputs	Y	Y	Y
18.1.1.2 - On-site heat generation from renewables - other wood biomass	Y	Y	Y
18.1.1.3 - On-site heat generation from renewables - non-wood based renewable heat	Y	Y	Y
18.1.2.1 - On-site electicity generation from renewables - residues from process	Y	Y	Y
18.1.2.2 - On-site electicity generation from renewables - other wood biomass	Y	Y	Y
18.1.2.3 - On-site electicity generation from renewables - non-wood based renewable electicity	Y	Y	Y

18.1.3.1 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - residues from process	Y	Y	Y
18.1.3.2 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - other wood biomass	Y	Y	Y
18.1.3.3 - On-site fuel generation from renewables excluding fuel used for mill site heat and electricity generation and excluding fuel that is used as a product further in the FW3 - Non-wood based renewable fuel production	Y	Y	Y
18.2 - Energy use	Y	Y	Y
18.2.1.1 - Energy use - Heat from renewable sources	Y	Y	Y
18.2.1.2 - Energy use - Heat from fossil sources	Y	Y	Y
18.2.2.1 - Energy use - Direct fuel use - renewable fuel	Y	Y	Y
18.2.2.2 - Energy use - Direct fuel use - fossil fuel	Y	Y	Y
18.2.3.1 - Electricity use - from 100% renewable sources	Y	Y	Y
18.2.3.2 - Electricity use - from 100% fossil sources	Y	Y	Y
18.2.3.3 - Electricity use - from the grid	Y	Y	Y
19.1 - Greenhouse gas emissions	Y	Y	Y
19.1.1. Greenhouse gas emissions from machinery	Y	Y	Y
19.1.2. Greenhouse gas emissions from wood combustion	Y	Y	Y
19.2 - Carbon stock	Y	Y	Y
19.2.1 - Carbon stock in woody living biomass (above ground)	Y	Y	Y
19.2.2 - Carbon stock in woody living biomass (below ground)	Y	Y	Y
19.2.3 - Carbon stock in woody dead wood	Y	Y	Y
19.2.4 - Carbon stock in soils of forest	Y	Y	Y
20.1.1.1 - Distance by mode - road transport - loaded	Y	Y	Y
20.1.1.2 - Distance by mode - rail transport - loaded	Y	Y	Y
20.1.1.3 - Distance by mode - water transport (inland waterways) - loaded	Y	Y	Y
20.1.1.4 - Distance by mode - water transport (maritime - sea-going ships) - loaded	Y	Y	Y
20.1.1.5 - Distance by mode - air transport - loaded	Y	Y	Y
20.1.2.1 - Distance by mode - road transport - unloaded	Y	Y	Y
20.2.1.1 - Freight volume - road transport - loaded capacity	Y	Y	Y
20.2.1.2 - Freight volume - rail transport - loaded capacity	Y	Y	Y
20.2.1.3 - Freight volume - water transport (inland waterways) - loaded capacity	Y	Y	Y
20.2.1.4 - Freight volume - water transport (maritime - sea-going ships) - loaded capacity	Y	Y	Y
20.2.1.5 - Freight volume - air transport - loaded capacity	Y	Y	Y
21.1 - Water use (freshwater intake by industry) [relevant for industry]	Y	Y	Y
21.2 - Water use (of the forest ecosystem)	Y	Y	
21.2.1 - Water use (of the forest ecosystem) - Evapotranspiration from the system	Y	Y	
21.2.2 - Water use (of the forest ecosystem) - Groundwater recharge	Y	Y	
22.1 - Forest and Other Wooded Land Area	Y	Y	Y
22.2.1 - Total volume above ground with stump over-bark			
22.2.2 -Total volume above ground with stump under-bark	Y	Y	
22.4.1 - Balance of increments and fellings: Net annual increment	T	T	
22.4.2 - Balance of increments and fellings: Volume of felled trees	T	T	
23.1.6 - site nutrient budget averaged over total rotation period (N, P, K, Ca, Mg)	Y		
23.2 - Soil compaction from machine operations			

24.1.1 - Water pollution - organic substances (biochemical oxygen demand)	Y		Y
24.1.2 - Water pollution - nutrients (nitrogen, phosphorus) as Nitrogen or TKN (Total KJELDAHL Nitrogen)	Y		Y
24.2.1 - Non-greenhouse gas emissions into air - CO	Y		Y
24.2.2 - Non-greenhouse gas emissions into air - NOx	Y		Y
24.2.3 - Non-greenhouse gas emissions into air - SO2	Y		Y
24.2.4 - Non-greenhouse gas emissions into air - NMVOC	Y		Y
25.2.1. - Volume of standing deadwood	Y	Y	
25.2.2. - Volume of lying deadwood	Y	Y	
25.3.1 - Area of Protected forests according to MCPFE	Y	Y	
26.1.1 - Area with damage classified by damaging agent - biotic	Y		
26.1.1.1 - Area with damage classified by damaging agent - biotic - insects and diseases	Y		
26.1.1.2 - Area with damage classified by damaging agent - biotic - wildlife and grazing	Y		
26.1.2 - Area with damage classified by damaging agent - abiotic	Y		
26.1.2.1 - Area with damage classified by damaging agent - abiotic - fire	Y		
26.1.2.2 - Area with damage classified by damaging agent - abiotic - storm, wind	Y		
26.1.2.3 - Area with damage classified by damaging agent - abiotic - snow, drought, mudflow, avalanche and other identifiable abiotic factors	Y		
26.1.3 - Area with damage classified by damaging agent - human induced	Y		
26.2 - Damage-induced wood supply	Y		
27.1 - Generation of waste in total	Y	Y	Y
27.1.1 - Not classified as hazardous waste	Y	Y	Y
27.1.2 - Hazardous waste	Y	Y	Y
27.2.1 - Waste to material recycling	Y	Y	Y
27.2.2 - Waste to incineration	Y	Y	Y
27.2.3 - Waste to landfill	Y	Y	Y

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).

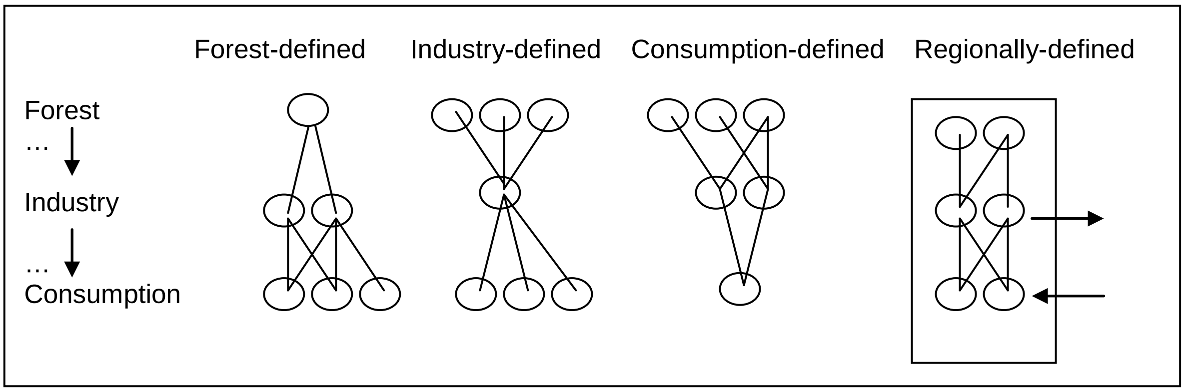

Figure 13. Alternative ways of defining FWCs.

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.