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EFORWOOD

Tools for Sustainability Impact Assessment

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Description of modelling framework

Deliverable D1.4.5
First prototype TOSIA-FWC
in open source technology for single chains

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EFORWOOD

Sustainability Impact Assessment
of the Forestry - Wood Chain

WP 1.4 TOSIA- Tool for Sustainability Impact Assessment

Deliverable D1.4.3

Description of modelling framework

Deliverable D1.4.5

First prototype TOSIA-FWC
in open source technology for single chains

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Date: 26. February 2007 (final version)

Executive Summary

Scope and purpose of the report

This combined deliverable report 1.4.3/1.4.5 presents ToSIA (Tool for Sustainability Impact Assessment), predominant product of EFORWOOD. ToSIA is being developed as a decision support tool for Sustainability impact assessment of the European Forestry Wood Chain (FWC) and subsets thereof (i.e. selected Single FWCs and Case Studies with multiple regional FWCs). ToSIA will allow various end-users, such as the forest-based industry, national and international policy makers, and researchers, 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).

The purpose of this document is to explain the general approach that ToSIA takes to assess the sustainability of FWCs. This delivery report provides a comprehensive documentation of the ToSIA modelling framework, referring to other documents for more detailed technical descriptions of the components. The report aims to inform both the researchers in other subprojects as well as interested stakeholders and the general public about the sustainability impact assessment (SIA) approach in

EFORWOOD.

Attached to the model documentation is the first ToSIA prototype. In the Annex the features of the first prototype are outlined, including instructions how to use the prototype. The prototype itself with more detailed documentation of the Java code is attached in the file tosia1.zip.

From sustainability of wood supply to Sustainability impact assessment of the forest-based sector

Since the Earth Summit in Rio de Janeiro in 1992 (UNCED), both forests and forestry have been added to the international agenda because of concerns about the sustainability of forests regarding biodiversity and its economic and social contribution to the development of the local communities. The forest-based sector has been at the forefront during the last 10-15 years in operationalising the sustainability concept and developing principles, criteria and indicators for sustainable forest management (SFM). Criteria and indicators have been developed to describe and help monitor progress in achieving SFM through several international, regional and national processes and fora.

Assessing sustainability of the forest-based sector means measuring environmental, economic, and social indicators for production technologies and other processes in the FWC, (see Wilhelmsson 2001). *Sustainability Impact Assessment* of the FWC means analysing the impact of changes, for example policy changes or technology changes, on the environmental, economic, and social sustainability indicators.

Indicators permit operationalising the concept of sustainability. In a generic sense, indicators can be viewed as factors or variables that can be used to measure the status and change of a system or process. The use of indicators allows for deconstructing of the sustainability assessment problem into manageable bits that can lend themselves to more formal or structured analysis

Review of existing tools and classification of the ToSIA model

Several existing tools from the literature are briefly presented with a focus on similarities and limitations of the approaches for the application in sustainability impact assessments for the FWC. None of the existing tools addressed all three sustainability dimensions along the whole FWC in a balanced way. Consequently the decision was made to develop ToSIA, the modelling framework for sustainability impact assessment of FWCs.
ToSIA will be developed as a dynamic sustainability impact assessment model that is analysing environmental, economic, and social impacts of changes in forestry-wood production chains, using a consistent and harmonised framework from the forest to the end-of-life of final products.

The Sustainability impact assessment approach in EFORWOOD

The SIA of the forest-based sector in EFORWOOD builds on the conceptual representation of FWCs as chains of value-adding production processes. In ToSIA, the analytical framework is organised in a sequence of three main hierarchical levels: modules, stages, and processes. Four project *modules* are organisational representations of the four main phases of a FWC: Forest resources management, Forest to industry interactions, Processing and manufacturing, and Industry to consumer interactions. A module consists of several *stages*. Stages define natural steps in the FWC. One stage can be characterized by optional *processes*, which means that alternative FWCs can be produced by switching to different processes within the same stage. In ToSIA, a FWC consists of a number of interconnected processes. Multifunctionality of forests and levels of sustainability of the whole FWC are addressed by selecting sustainability indicators in relation to every defined process along the chain.

In ToSIA the sustainability impact assessment of each alternative FWC will be determined by aggregation of indicator values along the chain. This exercise requires the use of evaluation methods such as Multi-Criteria Analysis (MCA) or Cost-Benefit Analysis (CBA; see chapter 4.6). The main exercise behind these techniques is to transfer of the original indicator value onto a common scale of preferability. It is this common scale that eventually allows to aggregate indicators by summing up the dimensionless preference values a decision maker or a stakeholder assigns to them (i.e., the comparison of “apples and pears”).

By comparing alternative FWCs in terms of sustainability it is possible to improve the sustainability of FWCs and the trade-offs between different sustainability indicators can be identified.

Changes in the sustainability of the FWC will be analysed using *scenarios* of future conditions. Factors changing the future are tentatively grouped into three categories:

- Global trends: e.g. world market, climate change.
- EU policies: e.g. affecting taxation of fossil fuel consumption, subsidies for utilization of renewable energies, nature conservation policies.
- Innovative technology (i.e. internal changes within FWC); e.g. changes in forest management, innovation in production technology, development of new products

The scenarios will result in alternative FWCs with different sustainability impacts compared to the current FWCs.

Description of the ToSIA modelling framework

ToSIA assesses sustainability of existing FWCs as well as impacts on sustainability of internal and/or external drivers such as global change, EU policy change or technological innovations.

ToSIA will be developed in EFORWOOD for Sustainability Impact Assessments at three different scales:

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

The ambition is to cover 60-80 % of the material flows in the whole European FWCs including all major forest types, production lines and wood based products.

The ToSIA modelling framework is based on the following components: (1) the project modules (M1-M5) of EFORWOOD, that is, the areas of expertise (researchers) in the project using specific models and data to provide information about production processes, indicator values and material flows to the database; (2) the Database, where information e.g. on sustainability indicators is stored and organised in such way that permits efficient harmonisation with the software; (3) the software, which enables dynamic interaction with users/stakeholders for defining specific FWCs and criteria on sustainability, reads sustainability information related to the defined FWCs from the database, and calculates results on sustainability for comparing the selected chains based on evaluation methods.

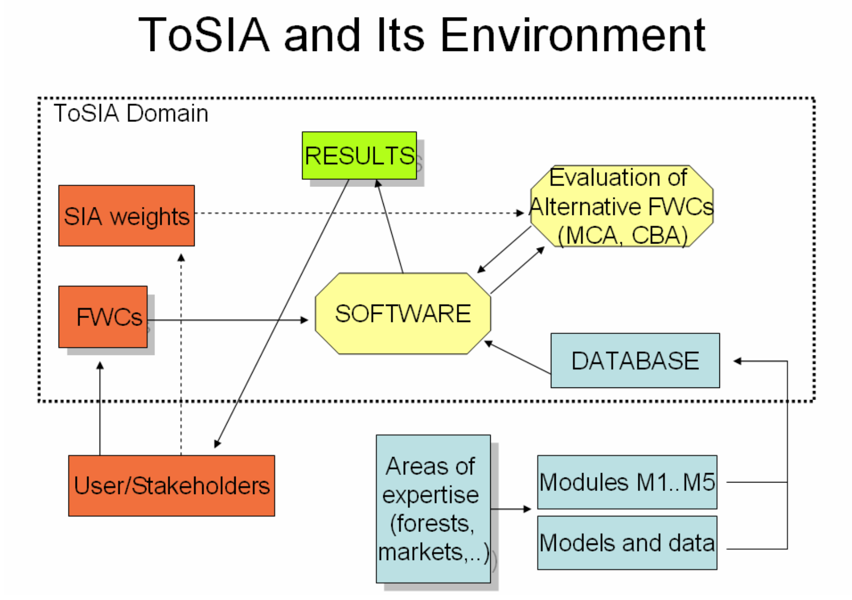


Figure 0.1. ToSIA and its environment: Areas of expertise (researchers) in the project provide information (e.g. indicator values) to the database, where the information is stored and organised in such way that permits efficient harmonisation with the software. Dynamic interaction (through a user friendly interface) with users/stakeholders for defining specific FWCs and criteria on sustainability is enabled by the software (heart of the system), which afterwards reads sustainability information related to the defined FWCs from the database, and calculates results on sustainability using evaluation methods, finally delivered to the user (through the interface) for comparing the selected chains.

Table of Contents

1 Introduction

The objective of EFORWOOD is to develop a decision support tool for Sustainability impact assessment of the European Forestry Wood Chain (FWC) and subsets thereof (i.e. selected Single FWCs and Case Studies with multiple regional FWCs). In EFORWOOD the FWC is structured in the following four parts:

- Forest resources management
- Forest to industry interactions
- Processing and manufacturing
- Industry to consumer interactions.

The decision support tool ToSIA (Tool for Sustainability Impact Assessment) will be the predominant product of EFORWOOD. In ToSIA, a FWC consists of a number of interconnected processes[1] and sustainability is determined by economic, environmental, and social indicators. Multifunctionality of forests and levels of sustainability of the whole FWC are addressed by selecting sustainability indicators in relation to every defined process along the chain. ToSIA will allow various end-users, such as the forest-based industry, national and international policy makers, and researchers, to analyse the 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).

The purpose of this document is to explain the general approach that ToSIA takes to assess the sustainability of FWCs. This delivery report provides a comprehensive documentation of the ToSIA modelling framework, referring to other documents for more detailed technical description of the components. Attached to the model documentation is the first ToSIA prototype. The report aims to inform both the researchers in other subprojects as well as interested stakeholders and the general public about the sustainability impact assessment (SIA) approach in EFORWOOD.

1.1 Sustainability and Sustainability Impact Assessment in the Forest-based sector

Over the last few years a significant body of work has emerged about the principle of sustainability. At the global level, the Brundtland report (World Commission on Environment and Development. 1987) brought forward the concept of sustainable development which means a development meeting the *needs of the present without jeopardising the ability of future generations to meet their own needs*. Since the Earth Summit in Rio de Janeiro in 1992 (UNCED), both forests and forestry have been added to the international agenda because of concerns about the sustainability of forests regarding biodiversity and its economic and social contribution to the development of the local communities. The importance of considering the *temporal*

[1] For details on definition of process and products in the scope FWCs, please see chapter 2 in this document

and spatial dimensions of sustainability has been also stressed in several studies (Gray 1991, Conway, 1994).

As entering into the 21st century, the sustainability paradigm has been extended to include whole economic sectors. Not only the forest production, but also the whole set of production chains using forest resources, should be evaluated in the SIA of FWCs. *Assessing sustainability* of the forest-based sector means measuring environmental, economic, and social indicators for production technologies and other processes in the FWC, (see Wilhelmsson 2001). *Sustainability Impact Assessment* of the FWC means analysing the impact of changes, for example policy changes or technology changes, on the environmental, economic, and social sustainability indicators.

1.2 Sustainability Indicators

The forest-based sector has been at the forefront during the last 10-15 years in operationalising the sustainability concept and developing principles, criteria and indicators for sustainable forest management (SFM) that would take into account regional and national variations. Criteria and indicators have been developed to describe and help monitor progress in achieving SFM through several international, regional and national processes and fora (e.g. Ministerial Conferences on the Protection of Forests in Europe, Strasbourg 1990, Helsinki 1993, Lisbon 1998, Vienna 2003 and the upcoming conference in Warsaw 2007 etc.). But also the European Union has adopted sustainable development indicators in 2005, (European Commission 2005b).

Sustainability indicators have also been adopted in the SIA of World Trade Organisation negotiations: various impacts based on the three sustainability principles have been listed e.g. by affected country or group of countries, or by product (see Zhu et al. 1998; Kangas and Baudin 2003; Vasara et al. 2005).

The sustainability of the whole FWC should be addressed by analysing and selecting sustainability indicators which reflect the multiple benefits of forest resources and all three pillars of sustainability (Kirkpatrick & George 2005; Päivinen & Lindner 2005). The domains of the sustainability of the FWC include as examples:

Environmental: energy generation and use, greenhouse gas balance, transport, water use, recycling and recovery, emissions to soil, water and air,
Societal: employment, wages and salaries, occupational safety and health, education and training,
Economic: gross value added, production costs, welfare economic effect of externalities.

However it should be added that this division remains problematic as some indicators will address i.e. environmental and economic aspects at the same time. Therefore sometimes it will be difficult to assign them to the three dimensions of sustainability (Deliverable report D1.1.1).

In a generic sense, indicators can be viewed as factors or variables that can be used to measure the status and change of a system or process. Indicators permit operationalising the concept of sustainability. The use of indicators allows for deconstructing of the sustainability assessment problem into manageable bits that can lend themselves to more formal or structured analysis (Mendoza and Prabhu, 2002). Indicators for SIA can be quantitative (tons of C, person hours) or qualitative. Qualitative indicators can be converted to ordinal scale (*e.g.*, the naturalness of a forest stand can be classified as 1=natural, 2=semi-natural, 3=planted).

Some of the indicators may be relevant and used to assess processes throughout whole chains, e.g. production costs, employment, or greenhouse gas balance. Some others are clearly associated with only parts of the chain, such as biodiversity or generation of waste. A more detailed presentation of sustainability indicator concepts and the selection of suitable indicators can be found in Deliverable Report D1.1.1.

1.3 Purpose of the ToSIA model

The Tool for Sustainability Impact Assessment (ToSIA) of FWCs integrates 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 assesses sustainability of existing FWCs as well as impacts on sustainability of internal and/or external drivers such as global change, EU policy change or technological innovations.

ToSIA will be developed in EFORWOOD for Sustainability Impact Assessments at three different scales:

4) **Single FWC** applications
5) FWC analysis in **Case Studies** with regional focus
6) **European FWC** analysis

To meet user needs and requirements of different applications, several versions of ToSIA will be developed:

- ToSIA-FWC is the basic tool which calculates sustainability indicator values for the production processes of the FWC and aggregates them with arithmetic operations for the whole chain or parts of it. Aggregation of different indicators is not possible.
- ToSIA+E incorporates an evaluation module to enable integrated impact assessment of the sustainability of the FWC in terms of Cost-Benefit Analysis

(CBA) and Multi-Criteria Analysis (MCA). In the former, indicators are converted to commensurable monetary values as far as appropriate. In the latter multi-criteria decision-making approaches with the option to include judgements on indicator importance and indicator values by stakeholders will be taken into account. MCA enables the aggregation of indicators originally measured on different scales.

- ToSIA-U is a user-friendly version including a graphical user interface and context-help allowing fast learning and application of the tool. This version will also include parts of the functionality of ToSIA+E.
- A demonstration package of ToSIA-U with selected case study data and policy scenarios will be made available on the internet and it will also be used and disseminated in stakeholder training courses.

ToSIA receives input from two major sources: the EFORWOOD database and the user of the software. The database provides all information about indicator values for each alternative process along the chain that has been provided by the project-modules 2-5. The user selects a FWC for a given study level (e.g. a Case Study) and the system will then provide detailed information about indicator values and sustainability indices for every level considered along the chain (modules, processes). By comparing different alternative FWCs, sustainability impacts of external drivers and internal FWC innovations can be evaluated using CBA and MCA.

What type of questions can ToSIA answer?

The specific questions to be studied with ToSIA in EFORWOOD will be defined later by the policies and scenarios that will be selected in a structured process involving all Modules and interactions with stakeholders. The following *question types* can be addressed by ToSIA[2]:

- analysing the sustainability of a single FWC by presenting detailed indicator values and general aggregated results
- focusing analysis on a certain subset of indicator values, e.g. only the ecological values
- comparing two chains for differences in sustainability
- comparing sustainability of the same chain at two different timesteps (timesteps predefined to 2005, 2015, 2025)
- comparing the sustainability impacts of similar processes taking place in different geographical areas
- assessing the sustainability impacts of a policy compared to a base line (the actual policies to be assessed will be defined later).
- analysing the sustainability impacts of partial chains, or comparing two segments of chains for differences in sustainability impacts

[2] not all of these question types will be addressed in the EFORWOOD project. For example, the project will not focus on comparative sustainability assessments in different geographical areas. Also, analysis of sustainability impacts of partial chains is not planned with ToSIA.

ToSIA will evaluate such questions at fairly aggregate levels, that is chains of considerable size. It is not within the scope of EFORWOOD to evaluate specific plants, firms or identifiable groups of enterprises. Moreover, there are a number of issues that ToSIA cannot be used for, and a short non-exhaustive list includes:

- automatically identifying optimal policies based on certain predefined indicator value targets
- automatically optimizing the flow amounts, or creating optimal allocation of material flows (products) to processes
- comparing sustainability of wood products with sustainability of competing materials from other sectors (e.g. steel, concrete, plastics).

2 Terms and definitions

In this chapter we define important terms that are used in EFORWOOD, particularly in connection with the ToSIA modelling framework. They are presented here because the correct meaning of these terms is essential for the understanding of many methodological concepts documented in this report.

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, 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.

CONVERSION FACTORS

Mass in tons of Carbon is used as the information carrier for FWCs in ToSIA. The information carrier is the base 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 reference units such as m3 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 DoW 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.
Indicator values are calculated (usually in the Modules) per unit of material flow. In ToSIA they will be linked with the material flow in the selected FWC to calculate the *FWC Indicator value* (we still need to find a good term for this to separate it clearly from the indicator value per unit of mass/other reference).
Indicator values are produced for relevant processes. Selection of indicators will be specified for each process from the overall set of indicators. Values of these selected indicators will then be calculated by the process.

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 common units (e.g. tons of C, m^3, ha) should be known.

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.

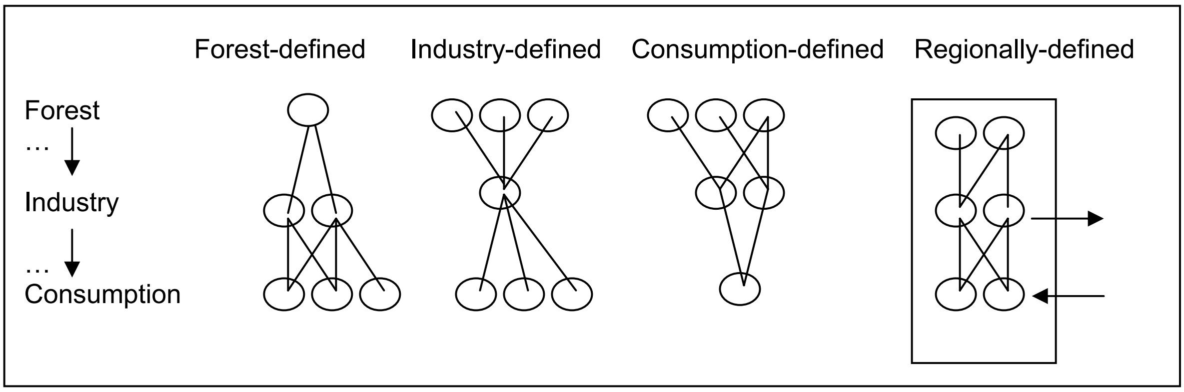
SCENARIOS
Scenario in the context of EFORWOOD is a combination of internal or external drivers and their impacts to the FWC. Different classes of drivers will be studied in the later stages of the project:

- 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. 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).



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 embedd into the three Case Studies in EFORWOOD phase II. All major EFORWOOD concepts such as indicator selection, sustainability assessment of the current FWC and scenario analysis of alternative FWCs will be applied first to the Test Chains/Single FWCs. Three Test Chains were studied in EFORWOOD:
- A regionally-defined spruce chain in Baden-Württemberg.
- A forest-defined pine chain in Scandinavia for furniture and bio-energy.
- A product-defined fine paper/newspaper chain mainly based on eucalyptus and including recycling.

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

ToSIA-FWC: basic version of ToSIA.

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

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

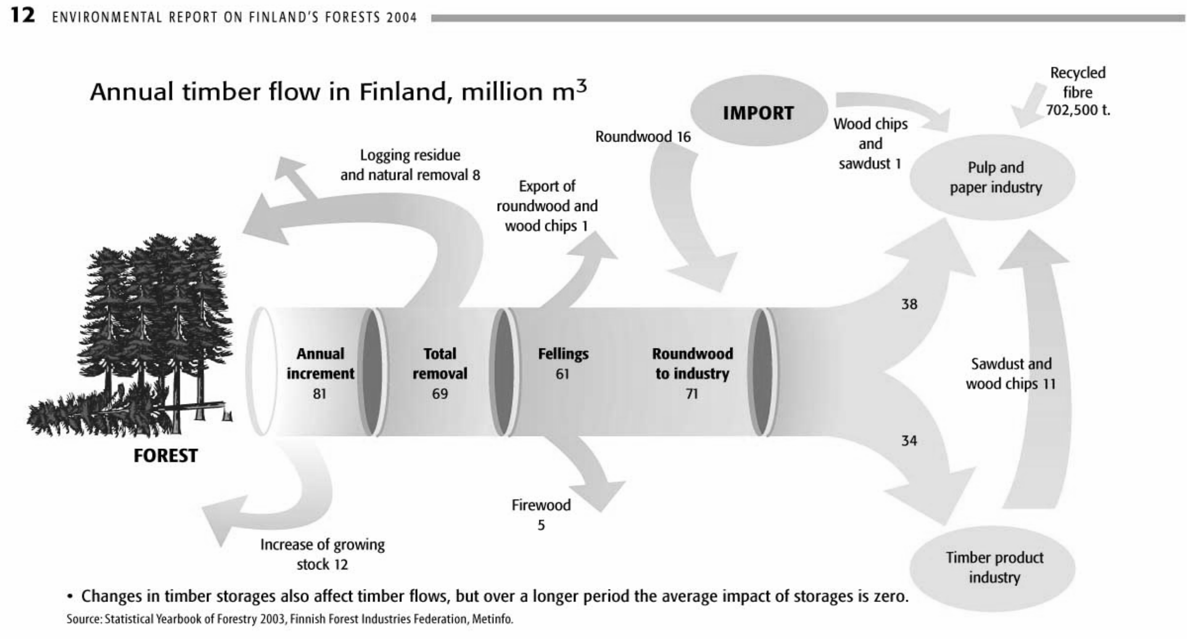


Figure 1. A simplified example of a FWC, the annual timber flow in Finland.

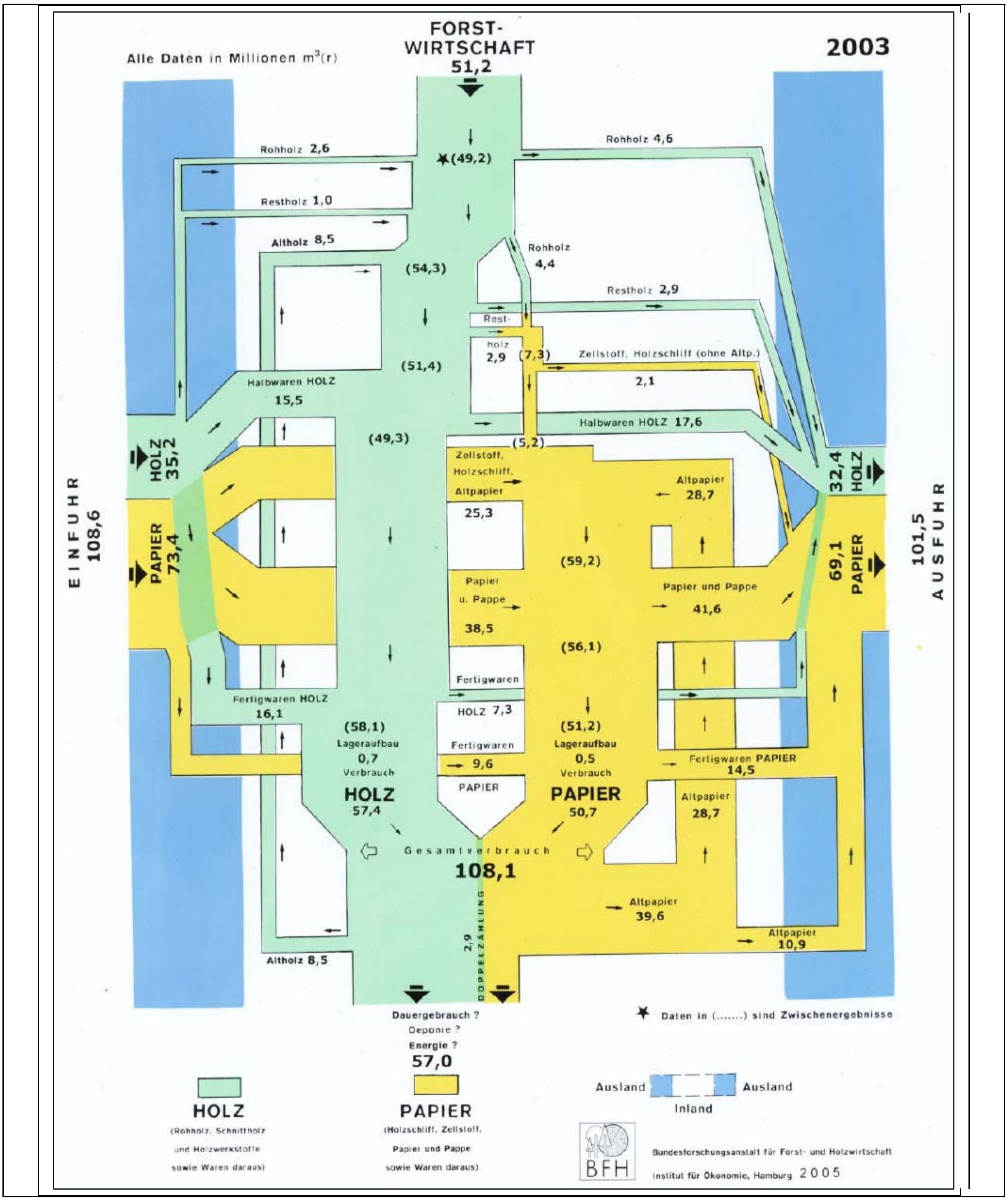


Figure 2. The annual flow of timber and wood products in Germany in the year 2003 (Dieter, 2005). All flows are indicated in Mio m3.

3 A review of previous work

What tools are already existing / available?

3.1 FWC flow statistics

Based on the forestry statistics and production figures of the forest industries, most European countries have good information on the volumes of wood-material flow related to their FWCs. In Figures 1 and 2 two examples are given from Finland and Germany. These statistics, however, only refer to production volumes and do not address aspects of sustainability related to environmental, social or economic issues. However, these particular statistics, possibly converted to carbon flow volumes, could serve as a basis for sustainability assessment of forest-wood chain (Päivinen and Lindner, 2005).

3.2 Optimum allocation models

A representative example of optimum allocation models is the WoodCIM model (Usenius 2002; Song et al., 2005; Usenius and Song 2005; Usenius et al., 2006). WoodCIM is an integrated software system supporting decision making at sawmills, considering the whole wood conversion chain - from the forest to the end products.

Traditionally different stages of the wood conversion chain have operated independently with nobody taking responsibility for the chain as a whole. The stages involved in converting wood raw material to final products influence on each other as well as the result. To obtain a good economic result the chain must be seen in its entirety. Wood raw material must be chosen taking into account the requirements set for wood material of the final products. This is the only way for optimal utilisation of wood raw material.

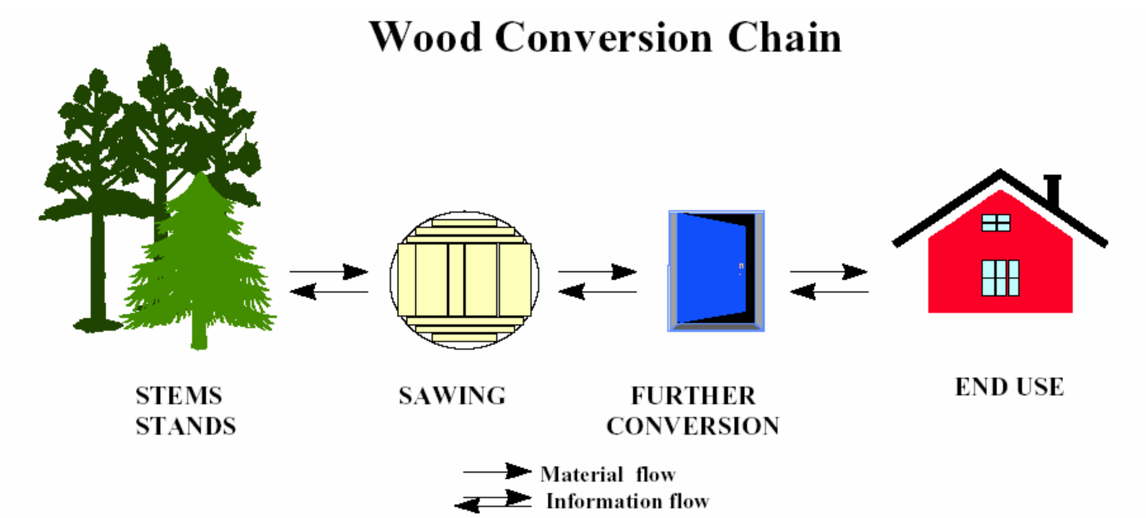


Figure 3: Phases in wood conversion chain are interacting to achieve maximum profitability (Usenius, 2002).

There are several questions to be answered affecting profitability in wood working companies e.g.

- What is the value of the stand on the basis of the product specification?
- What is the optimum selection of the stands?
- What are the bucking instructions according to the actual products?
- What are the optimum log sorting procedures?
- What are the optimum grading instructions for sawn timber, flitches for manufacturing of components?
- What are the optimum set-ups for the logs?
- What are the optimum wood product families – standard products or component matching the available wood raw material?
- What are the optimum further conversion concepts?

WoodCIM was designed to deal with the above mentioned questions. The system is comprised of the following integrated software modules:

- Simulation program for predicting the volume and value yield by sawing a log or a log class
- Program for optimising the limits of sawlog classes
- Sawing model based on linear programming for production planning
- Integrated optimising model "from stump to final product", supporting bucking decisions

The different modules of the integrated software focus on maximising profit or value yield, taking into consideration non-homogeneous wood raw material, variation as well as the process and market variables. The software modules also allow for creation of different scenarios, i.e. theoretical production lines and products, which allows studying their potential profitability.

3.3 LCA

"Life cycle assessment" (LCA) has been applied in forestry since the 1990s to evaluate the environmental impact of forestry and forest products. The major reasons for performing LCAs are (Frühwald and Solberg 1995):

- to obtain quantified and reliable information for the emotive debate on the environmental impact and benefits of wood products so that this information can be used by industry and policy makers,
- to improve production and recycling techniques by minimizing steps with high environmental impact or choosing different processing routes to reduce environmental impact or highlighting compatibility between processing,

- to highlight areas where information on the environmental impact of products is still unknown or uncertain,
- to enable comparison between different materials (provided that products are used for the same purposes - e.g. railway sleepers from wood, concrete, steel).

LCA already has been applied in many parts of the FWC:

- nursery (Aldentun, 2002)
- forest production (Schweinle 1998, 2000, 2001),
- saw milling industry, (Speckels et al. 2000)
- wood products and substitutes (Scharai-Rad and Welling, 2002)
- derived timber products industry (Zimmer and Kairi 2000; Rivela, et al. 2006)
- flooring industry (Nebel 2003),
- paper industry (e.g. Lopes et al. 2003, Dias et al.
- bio-energy (Jungmeier et al. 2003)
- recycling industry (Speckels 2001, Speckels, et al. 2001)

LCA studies have been used to identify the environmental impacts of the industries, to reduce such impacts, and for assessing the greenhouse gas balance of wood materials in comparison to other materials . In a recent study, Dias et al. (2006) have demonstrated the application of LCA to assess the environmental sustainability of paper making.

3.4 Causal Chain Analysis

Causal chain analysis (CCA) has been used to assess sustainability impacts of World Trade Organisation negotiations in the forestry sector (Katila and Simula 2004). The aim of the method is to establish a causal link between a proposed trade measure and a change(s) in sustainability condition(s) in the forest sector. CCA first links changes in a trade measure to changes in incentives (prices) and opportunities (expanded market access), which can influence the production system and trade flows. Then in a second step it links changes in the production system to sustainability impacts (Figure 4).

Katila and Simula (2004) stressed that sustainability of forestry is influenced by a number of factors, many of them related to national policies. Successful application of CCA requires forming a “systems model” of all the main factors affecting sustainability of forestry. A conceptual framework for this assessment was proposed by:
- structuring the various factors influencing sustainability into
  - underlying, immediate and direct causes (the three levels in Figure 4)
  - categories reflecting main national or international policy measures
- clarifying the role of international trade in relations to other factors having sustainability impacts;

• developing causal relationships between changes in trade measures and consequently in prices and production systems; and
• identifying mitigation and enhancement measures.

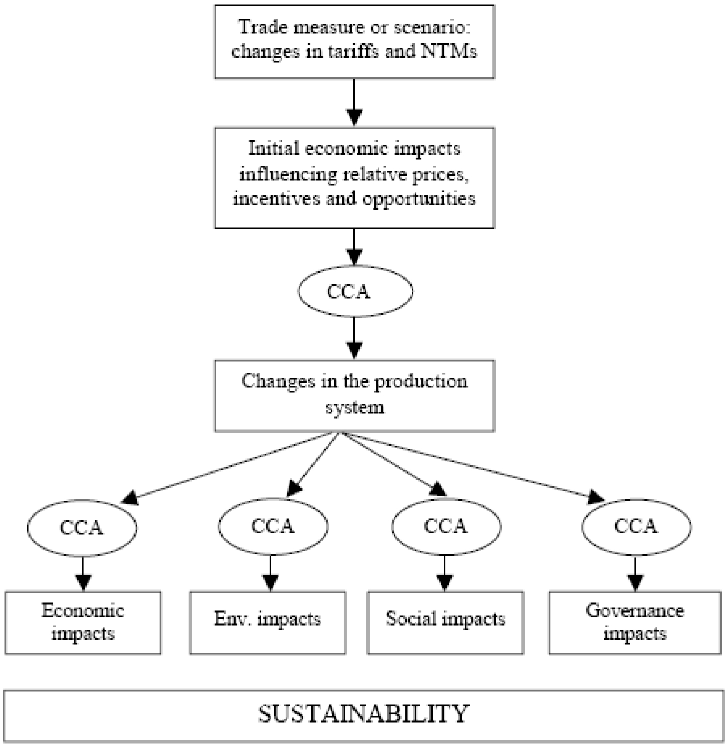


Figure 4: Application of causal chain analysis (CCA) in forest sector sustainability impact assessment of World Trade Organisation negotiations (Katila and Simula 2004).

3.5 The SIAT tool of the SENSOR project

The Sustainable Impact Assessment Tool (SIAT) is the central product representing the integrated modelling approach of the SENSOR project (6th EU Framework Program). The knowledge-based model SIAT enables end users to assess the effects of land-use relevant EU-policies and evaluate the impacts against sustainability criteria. SIAT is a problem- and user-oriented tool. SIAT contains a dual approach that a) analyses by ‘impact identification’ the multifunctional land use as well as related sustainability indicators and subsequent b) assesses their fulfilment of sustainable tolerance limits through ‘sustainability (risk) assessment’. Response functions are used to translate policy variables into land use claims and the land use claims into indicator values. The model framework focuses on cross-sectoral trade offs and side effects of the six sectors agriculture, forestry, energy, transport, nature conversation and tourism. The regionalization of results is rendered in clustered European regions (NUTSx), which take socio-economic as well as bio-physical location factors into account. The model concept is based on a wide set of pre-run model results that are integrated to a consistent frame, both from small scales (pixel-level 5x5 km) to aggregated level (national and EU-level) across the 6 sectors (see www.sensor-ip.org for more information).

3.6 Pathway analysis

A European research network on pathway analysis was developed from the beginning of the Nineties to evaluate the social and environmental costs of energy in Europe. These activities resulted in the EC project ExternE (External costs of Energy) (European Commission, 2003). The goal of the ExternE project was to determine external costs caused by energy production and consumption of energy-related activities, i.e. the monetary quantification of its socio-environmental damage. An external cost, also known as an externality, arises when the social or economic activities of one group of persons have an impact on another group and when that impact is not fully accounted, or compensated for, by the first group. Thus, a power station that generates emissions of SO_2, causing damage to building materials or human health, imposes an external cost. Research in this field aims to provide a basis for improved sustainable policies for energy and transport.

The impact pathway approach was developed within the ExternE project as a bottom-up-approach in which environmental benefits and costs are estimated by following the pathway from source emissions via quality changes of air, soil and water to physical impacts, before being expressed in monetary benefits and costs. The use of such a detailed bottom-up methodology − in contrast to earlier top-down approaches − was chosen to calculate site-dependent external costs (cf. local effects of pollutants). An illustration of the main steps of the impact pathway methodology applied to the consequences of pollutant emissions is shown in Figure 5. Two emission scenarios are needed for each calculation, one reference scenario and one case scenario. The background concentration of pollutants in the reference scenario is a significant factor for pollutants with non-linear chemistry or non-linear dose-response functions. The estimated difference is the simulated air quality situation between the case and the reference situation is combined with exposure response functions to derive differences in physical impacts on public health, crops and building material. It is important to note, that not only local damages have to be considered − air pollutants are transformed and transported and cause considerable damage hundreds of kilometres away from the source. Hence, local and European wide modelling is required.

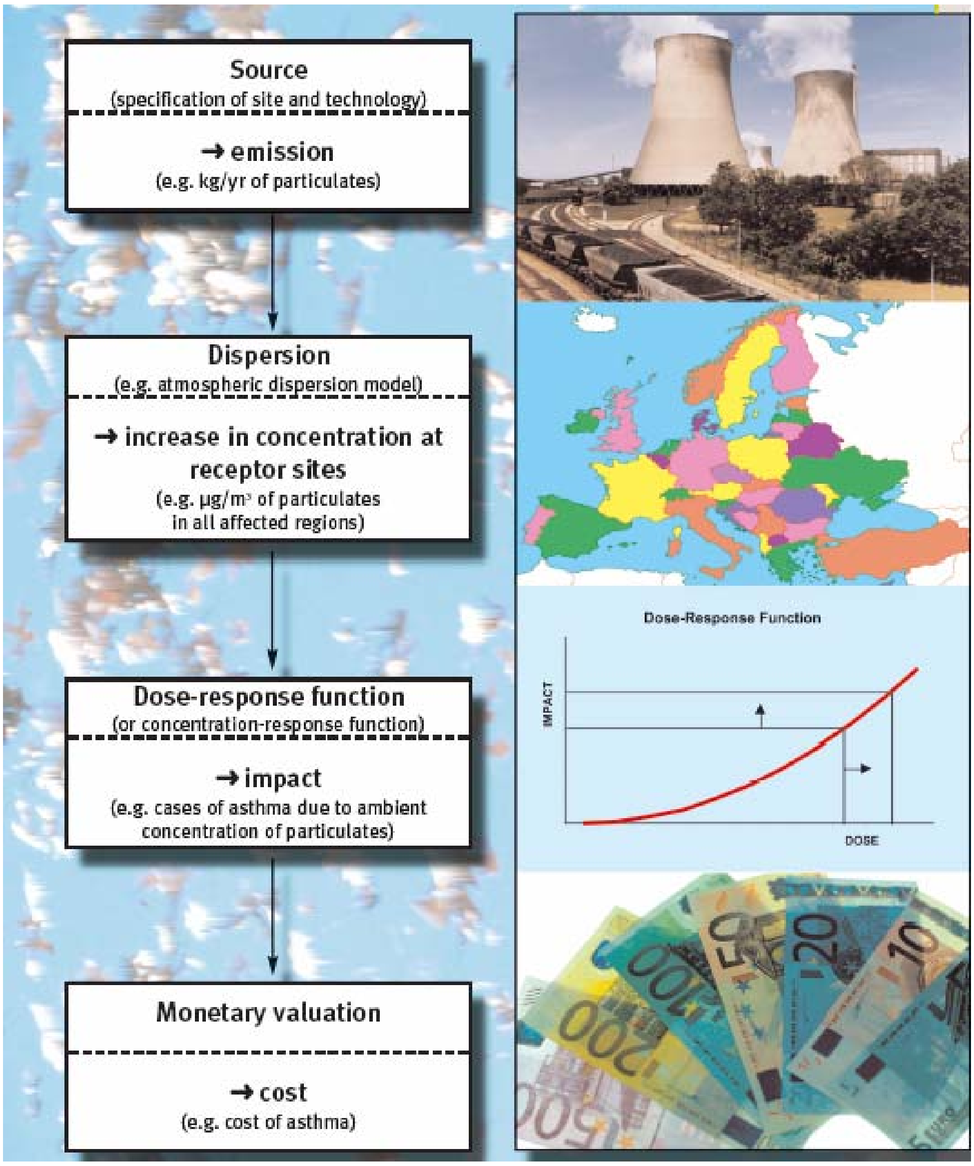


Figure 5: Main steps of the impact pathway methodology applied to the consequences of pollutant emissions (European Commission, 2003).

Regarding dispersion, not only atmospheric pollution is analysed, but also pollution in water and soil. Human exposure to heavy metals and some important organic substances (e.g. dioxins), which accumulate in water and soil compartments and lead to a significant exposure via the food chain, is represented in further models.

As a *next step* within the pathway approach, exposure-response models are used to derive physical impacts on the basis of these receptor data and concentration levels of air pollutants. The exposure-response models have been compiled and critically reviewed in ExternE by expert groups.

In the last step of the pathway approach, the physical impacts are evaluated in monetary terms. According to welfare theory, damages represent welfare losses for individuals. For some of the impacts (crops and materials), market prices can be used to evaluate the damages. However, for non-market goods (especially damages to human health), evaluation is only possible on the basis of the willingness-to-pay or willingness-to-accept approach that is based on individual preferences.

To perform the calculations the EcoSense model, an integrated software tool for environmental impact pathway assessment was developed and used. EcoSense provides harmonised air quality and impact assessment models together with a database containing the relevant input data for the whole of Europe (European Commission, 2003).

3.7 MCA application in SIA

Multi-Criteria Analysis (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. MCA can assist in transforming the rather broad sustainability concept into something operational and practical. SIA, despite its inherent complexity, can be formalised and conducted systematically because MCA have proved to be an effective tool for selecting, evaluating and aggregating the various indicators of forest sustainability.

Comparing alternative FWCs over a heterogeneous set of indicators on different measurement scales requires the transfer of the original indicator value onto a common scale of preferability (Seppälä et al., 2002).

This task involves subjective values, interests and expectations. It is this common scale that eventually allows to aggregate indicators by summing up the dimensionless preference values a decision maker or a stakeholder assigns to them (i.e., the comparison of “apples and pears”). Multi-criteria analysis is the overarching term for a set of methods which are specifically designed to lend support to this process by

(i) taking explicit account of multiple, conflicting indicators, criteria or objectives,

(ii) structuring a decision problem where the focus is on the comparison of a finite number of alternatives/alternative courses of action which are characterized by a set of indicator values covering the three dimensions of sustainability. The aim is to identify the most preferable option.

(iii) providing a formal model for such problems that can serve as a focus for discussion, and

(iv) offering a process that leads to rational, justifiable, and explainable decisions.

(v) enhance the participatory approach to decision making, where all stakeholders are involved, not only as information providers but also as decision makers.

Approaches of MCA can roughly be divided into three groups according to the way they deal with preference information and what kind of process will take place between the decision makers and the analyst. The groups are often referred to as: Multi attribute utility theory, outranking methods and voting methods (Kangas & Kangas, 2002).

Multi attribute utility theory is the most demanding group of methods with regard to preferences as it does not allow any incomparability. The aim of this type of methods is to gather the information of all the criteria into one unique synthesizing criterion. These methods can be summarised as a 4-step procedure: (1) set up the decision hierarchy of the study case by decomposing the problem into a hierarchy of interrelated elements (although this step is not mandatory; see Figure 6); (2) generate preference information based on direct rating, ranking or comparative judgement (*i.e.*, pairwise comparisons in AHP; Lootsma 1999, Schmoldt et al., 2001) of alternatives with regard to individual decision criteria; (3) estimate the relative weights of the elements in the decision hierarchy; and (4) once a weight has been assigned to each decision element in the established hierarchy, preference information at decision criterion level can be aggregated upstream in order to rank the different alternatives from the “best” to “worst”.

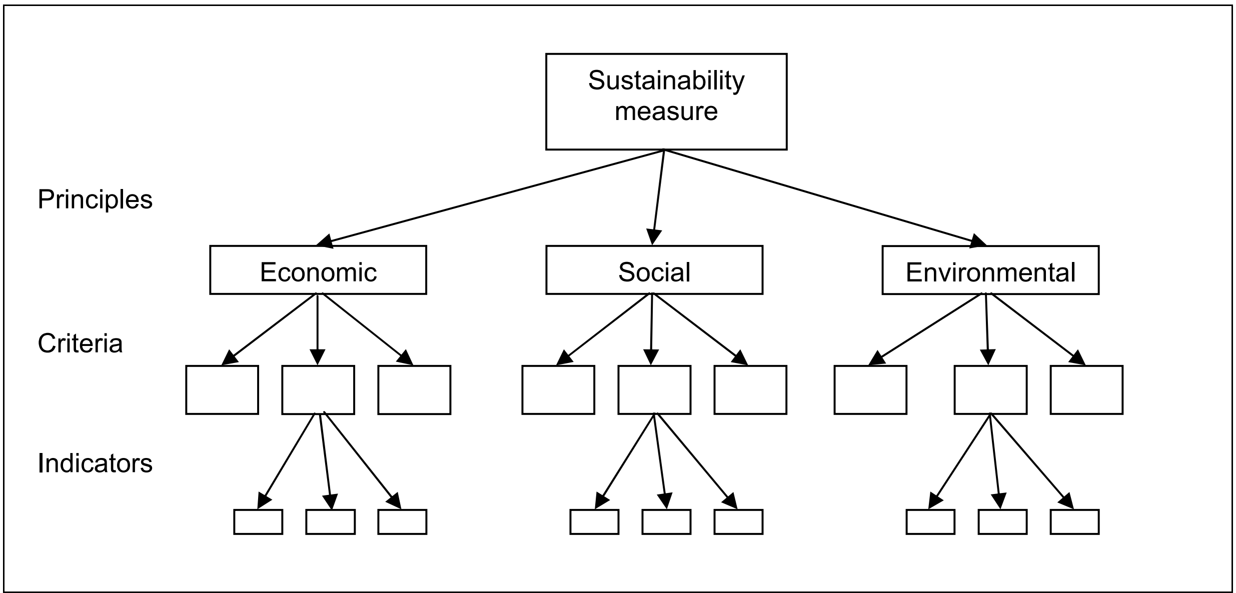


Figure 6. Hierarchical structure of criteria and indicators (see e.g., Prabhu et al., 1998). This figure is not complete and is used only to lay out the components of the C&I hierarchy. Hence, the blank boxes are included to denote a set of C&I elements that are too many to include in one figure.

Methods of the outranking type allow for incomparability between criteria, although the rule still tries to deal with the aggregation problem in a synthesizing, exhaustive and definitive way. In the same way as in multi attribute utility methods, sustainability scores are considered at the indicator level, but a decision hierarchy below the main sustainability pillars (principles in Figure 6) is not considered. Criterion weights are required, and if the criteria are not regarded as equally important, the weights may be derived by multi attribute utility methods. In outranking methods 2 or 3 thresholds per criterion are used to determine if for a given indicator two alternatives are equally good, one of them is weakly preferable, or one of them is strongly preferable (see *e.g*. Kangas et al., 2001; Pukkala, 2005).

Voting methods are especially suitable if there are several decision makers as in participatory and group decision making processes. This is in particular the case when there is a low amount/quality of information available that is required for decision making. There are several voting approaches proposed for multi-criteria analysis (e.g., Kangas et al. 2006). Well-known voting schemes are e.g., approval voting where each approved alternative gets a vote and the one with highest number of votes is the best, or, Borda count where the number of votes for the best choice relies on the number of alternatives. Other voting approaches may assign utility values in the wake of the voting procedure (Kangas & Kangas, 2002).

It is important to remark that the choice of a MCA method is not an exact science and, at present, there is no technique which unambiguously will lead to a conclusion of which method is the right one to use. Moreover, different methods may provide the decision makers with different solutions and in many cases the methods will be difficult to compare for the decision makers.

The readers are referred to PD1.5.2. for a more detailed explanation on how MCA will be used for SIA in ToSIA, and to PD. 1.4.4 for a description of the ToSIA interface with the evaluation software modules

Figure 7 shows an example of how MCA could be applied. Sustainability can be measured for each indicator on a scale between 0 (bad) and 1 (good), using some of the methods described above. Sustainability profiles could be applied for individual indicators along the chain (e.g. where are the most problematic processes regarding GHG emissions? where are most jobs? where is value added?) Results can be aggregated for each process step (across sustainability pilars) with resulting preference index values for each step. They can also be aggregated over the whole FWC, resulting in one single utility value, or aggregated in specific spatial regions of interest.

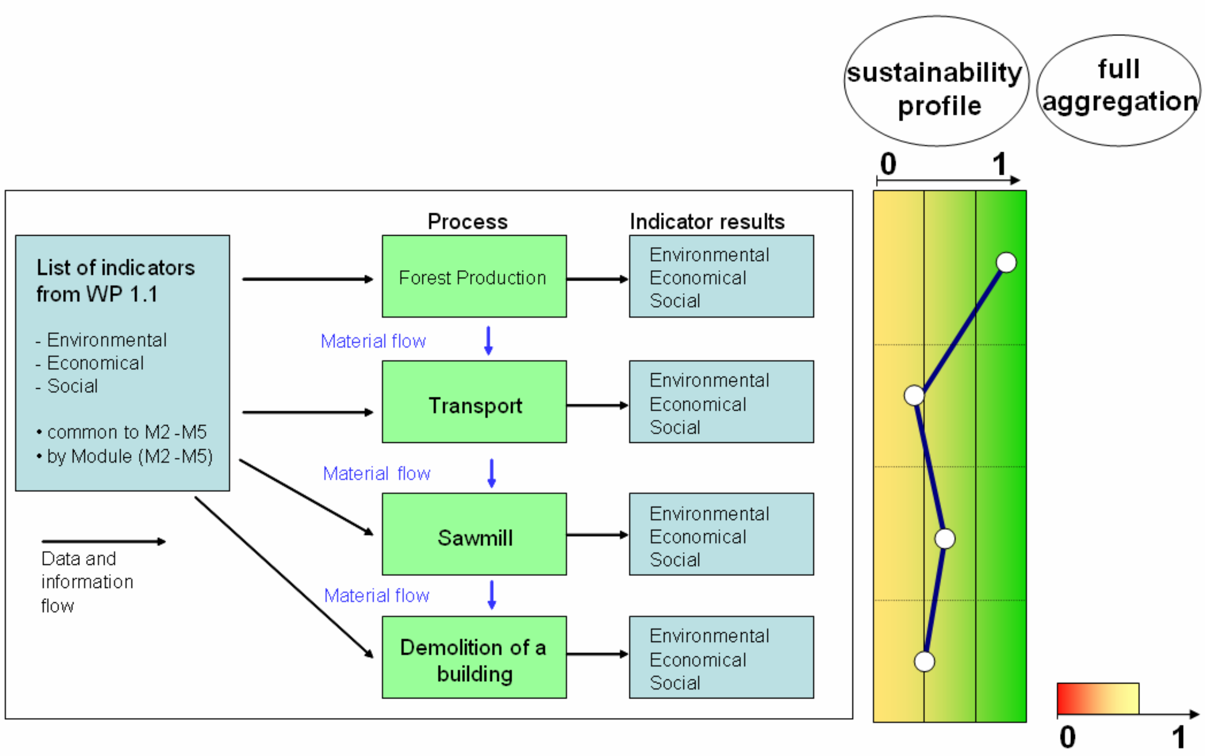


Figure 7. Simplified depiction of how sustainability evaluation could be used in TOSIA to calculate sustainability of a FWC. Full aggregation enables the comparison of alternative FWCs (right most picture), but it does not provide much information. Sustainability profiles calculated at the process or module level (as shown here) are preferable, because they highlight the key factors affecting sustainability of the FWC.

4 Developing a Methodology for Sustainability Impact Assessment of FWCs - the New ToSIA Model

The SIA of the forest-based sector in EFORWOOD builds on the conceptual representation of FWCs as chains of value-adding production processes (Päivinen & Lindner 2005). In ToSIA, the analytical framework is organised in a sequence of three main hierarchical levels: modules, stages, and processes (see Figure 3). Four project *modules* are organisational representations of the four main phases of a FWC: Forest resources management, Forest to industry interactions, Processing and manufacturing, and Industry to consumer interactions. A module consists of several *stages*. Stages define natural steps in the FWC. One stage can be characterized by optional *processes*, which means that alternative FWCs can be produced by switching to different processes within the same stage.

The simple FWC depicted by an arrow line in Figure 8 represents only one of many possible pathways to grow wood material and convert it to a final product. If individual processes in the FWC are modified, the associated sustainability (indicator values related to each process) will be directly affected. For example, if a harvester is used for cutting trees instead of manual felling, this process may become more economic, but the number of jobs in tree harvesting will most likely be reduced. Similarly, shifting the transport of wood from truck to railway – as set as a target in the EU strategies towards sustainability – would probably result in improved environmental indicators. In ToSIA the sustainability impact assessment of each alternative FWC will be determined by aggregation of indicator values along the chain. This exercise requires the use of evaluation methods such as Multi-Criteria Analysis (MCA) or Cost-Benefit Analysis (CBA; see chapter 4.5). By comparing alternative FWCs in terms of sustainability it is possible to improve the sustainability of FWCs and the trade-offs between different sustainability indicators can be identified.

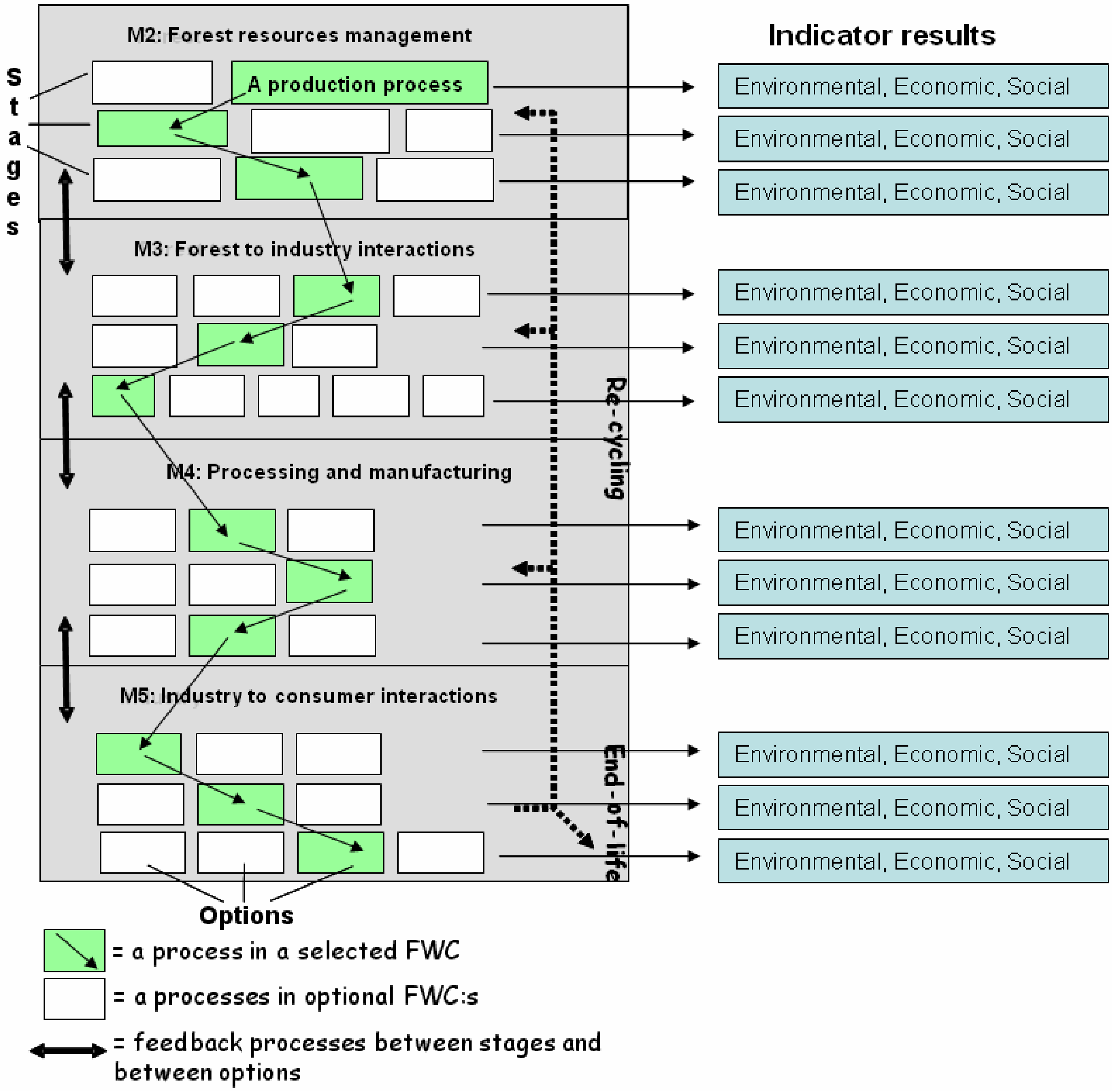


Figure 8. The methodological framework to assess the sustainability of FWCs. The shaded boxes represent processes in one FWC. Each process is linked with a set of environmental, economic and social indicators.

4.1 Linking sustainability indicators to processes

ToSIA calculates sustainability impacts by analysing environmental, economic, and social sustainability indicators for production processes along the FWC. ToSIA utilizes indicators selected from the framework of sustainability indicators for the FWC, which are developed by WP1.1 together with all partners (cf. deliverable D1.1.1), building on the existing experience from several existing indicator sets (see Table 1). This sustainability indicator framework will be the first comprehensive indicator set for the whole forest-based sector and it complements a similar selection of cross-sectoral sustainability indicators developed in the SENSOR-IP (Kristensen et al. 2006).

Table 1: Existing European & international sustainability indicator sets used in the development of the EFORWOOD sustainability indicator framework (see D 1.1.1 for more details).

	Hierarchical levels		
EU-SIA Guidelines[a]	32 topics	--	--
Eurostat – SDI[b]	15 level 1 – indicators	47 level 2 – indicators	99 level 3 – indicators
MCPFE[c]	---	---	35 indicators
CSD[d]	15 themes	40 sub-themes	60 indicators
PAIS[e]	5 themes	16 issues	57 indicators

a *Impact Assessment Guidelines* of the European Commission (European Commission 2005a); **b** *Sustainable Development Indicators for the European Union* presented by Eurostat (European Commission 2005b); **c** *Improved Pan-European Indicators for Sustainable Forest Management* of the Ministerial Conference on the Protection of Forests in Europe (MCPFE 2002); **d** *Indicators of Sustainable Development* of the Commission for Sustainable Development of the United Nations (United Nations 2006); **e** Rural Development Indicators, in the Report of the PAIS project, Phase 1. (*Bryden et al., 2002)*.

From the EFORWOOD indicator framework (see Deliverable D1.1.1) only some indicators respectively sub-classes have been selected for the first data collection and application in ToSIA. The ToSIA prototype application to Test Chains conducted in project months 11-13 included 14 indicators with about 40 sub-classes. The development of the EFORWOOD indicators is an ongoing process. Currently module-specific indicators especially for the project module 2 dealing with Forest resource management and project module 3 dealing with Forest to industry interactions are being prepared and discussed. It is foreseen that with more experience in data collection and sustainability assessment for Single FWCs and Case studies the list of whole chain indicators and module-specific indicators applied in ToSIA will be revised. Different versions of ToSIA may also use reduced subsets to make the calculation and analysis faster and more transparent.

All indicators included in the indicator framework have defined measurement units and efforts are under way to specify data collection protocols for the indicator collection to give a clear guidance on how to deal with questions like system boundaries (e.g. between production processes or the consideration of non-wood materials in the FWC). These data collection protocols will be added as an ANNEX to this Delivery report once they are finalised.

The indicator values are submitted to the EFORWOOD database from project modules 2-5. In most cases they are derived from available statistical data sources or they are generated from outputs of process-specific models available to M2-M5. Expert judgements are also used, particularly with qualitative indicators. In any case the indicator values reflect the best available knowledge about the sustainability of the processes included in the selected FWCs. Indicator values are defined in relation to a reference unit. The reference unit is one ha for process indicators for the Module 2 Forest resource management and one ton C content in the wood or wood product for all other process indicators of the project modules 3-5. The indicators may be reported with different reference units (x/m3 or x/t of a product) provided that conversion factors are available to convert the values in the database into the values per ton C content.

4.2 Tracking material flows along the FWC

The FWC is considered in ToSIA as a dynamic structure linking processes and describing the material flow entering and leaving each process. This structure results in a FWC, and is dynamic due to the fact that this structure can be altered in shape while still using the same static information on processes. For the base case all of this is essentially defined by the input from the M2-M5.

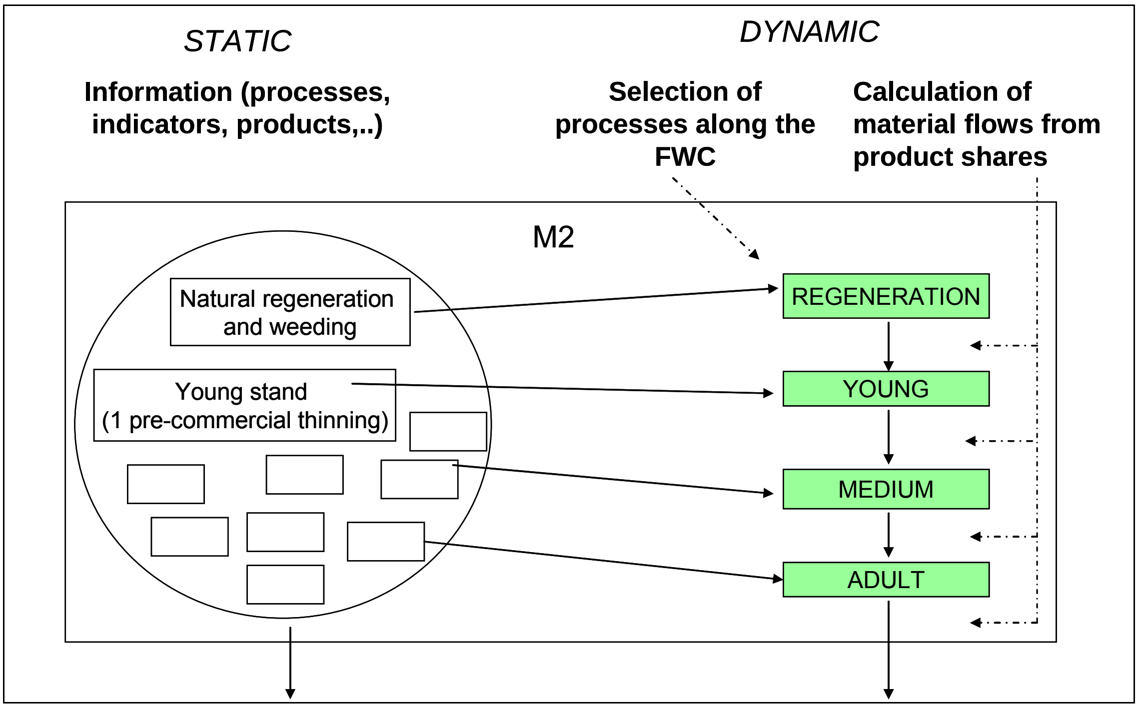


Figure 9: Functional components in ToSIA. FWCs can be defined in ToSIA by using the dynamic component of the system, which permits selecting optional processes for every considered stage in a Module. Information describing a selected process is available in the static component of the system, which gives a defined format to the data coming from the database. The material flow is calculated using product shares which are stored with the processes in the database.

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. When the ToSIA calculates sustainability impacts, it multiplies the flow with the relative indicator value to obtain the absolute indicator value. A change in the material flow amount results in different absolute indicator values.

The way that the calculation of flows takes place is explained in more detail in chapter 5.2.4. To start calculation of the flows, they must first be initialised by giving a starting flow - in the first prototype this is given at the boundary between the project modules M2 and M3. This starting flow is required for all the branches of a FWC which cross this boundary. The consecutive calculation of material flows along the FWC is using the information of product output shares relative to the input flow of each process, which is also stored in the static information about production processes in the EFORWOOD database.

It is of great importance for the realism of ToSIA calculations that the material flow volumes are correctly reported and estimated both for the initial flow (harvest volumes at the M2/M3 interface) as well as for the rest of the forest value chain. For the baseline reference the material flows will be carefully validated with independent statistical data for the reference year 2005.

Material flows along the FWC will often be affected by the scenarios that will be analysed in EFORWOOD. As discussed in more detail in chapter 4.4, the forest sector model EFI-GTM will be applied to modify material flows in the scenario calculations. The scenario impacts on material flows will be reported back to all other project modules (together with other socio-economic information) to ensure that consistent assumptions are applied along the whole FWC.

4.3 Spatial and temporal dimensions of sustainability

For sustainability impact assessment of FWCs the spatial and temporal dimensions of sustainability are a key issue to consider. In practice only a limited number of indicators can be used, which are sensitive to spatial and temporal changes, and also meet the requirements of ease of data collection and application (Varma et al., 2000).

Spatial dimension

Sustainability in the European forest sector can be considered at different geographic scales and administrative or management levels, that is, global, regional, national, or specific forest management units. In the evaluation of the chain, spatial issues may be of relevance to the end-users. It may be important to know where specific flows and sustainability impacts are taking place. Such information can form the basis for formulating strategies to remedy the potential problems.

In the EFORWOOD applications of ToSIA all indicators and material flows have a geographical reference, normally at the level of NUTS1, NUTS2, or NUTS3. Therefore, indicators should not be collected for specific forest stands or manufacturing units. Rather, they should reflect the average regional conditions of a certain management type or production technology (for the respective NUTS1-3 region). The ToSIA applications for Single Chain analysis, Case Studies and later European FWC analysis have increasing spatial coverage. Specific regional information across Europe is only collected in the last phase. The tool would also be suitable to assess scenario impacts that have a regional dimension, e.g. sustainability impacts of shifting production from one region to another. However, EFORWOOD will probably not focus on such investigations, partly because analysing regional differences in sustainability would require more intensive data collection that is beyond the resource capacity of the project and its current partnership.

Temporal dimension

EFORWOOD will first collect data on sustainability impacts of current FWCs based on data for the year 2005. If annual variability is strong, average values for the 3-5 last years will be used instead. Current FWCs are analysed in such a way that all processes in different stages of the chain occur simultaneously (business-as-usual). This means that planting, tending and harvesting as well as transport and industry processes are all analysed using current techniques and costs. Indicator values and volumes processed will be collected for the reference year (2005) and estimated for 2015 and 2025 using trend projections. Some forest resource indicators will also include a long-term sustainability dimension, because current management is affecting also the state of the forest in 2050 and beyond. The same applies to carbon sequestration in wood products. The future state related indicators can be integrated in the analysis using discounting or other evaluation methods. Development over time in temporal indicators may be mapped, and this information can be used in the evaluation module (CBA, MCA).

4.4 Analysing Scenarios of modified FWCs.

Changes in the sustainability of the FWC will be analysed using scenarios of future conditions. Factors changing the future are tentatively grouped into three categories:

- Global trends: e.g. world market, climate change.
- EU policies: e.g. affecting taxation of fossil fuel consumption, subsidies for utilization of renewable energies, nature conservation policies.
- Innovative technology (i.e. internal changes within FWC); e.g. changes in forest management, innovation in production technology, development of new products

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 next chapter 4.5).

EFORWOOD will define and study a limited number of scenarios (see box below) which will be applied consistently through-out the FWC. The scenarios will be specified with detailed storylines, characterising the underlying assumptions of the scenarios about the development of key variables, both environmental (e.g. climate conditions) and socio-economic (e.g. GDP development, energy prices, wood product demand). The final selection of scenarios will be made after extensive stakeholder consultations, including the EC.

Arithmetic example: calculating the possible number of processes in EFORWOOD case study and European FWC analysis. For each of these processes, indicator values have to be delivered (in the Test Chain application up to 40 indicator values were collected per process). The total number of values then needs to be multiplied with the number of baseline and scenario runs that will be implemented in EFORWOOD.	
Let us assume that a single FWC would have on average three **proc**esses per module	= total of **12 proc** in current FWC (a=12)
There will be **alt**ernative **proc**ess **opt**ions for most processes, sometimes even 2-3 per process	= approx **24 alt proc opt** per FWC (b=24)
In a case study there will be several FWCs. This number is difficult to estimate, perhaps 3-10 **cha**ins/**bra**nches in each part of the chain	= **7 cha/bra** (guesstimate) per part of chain (c=7)
We have three Case Studies	(d=3)
Total number of processes: (a+b)*c*d	36*7*3 = **756 processes (Case Studies incl. Single chains)**
The European FWC analysis will probably be more aggregated, but it will be made for 25 Countries.	
Let us assume a=8, b=12, c=5, d=25	20*5*25 = **2500 processes (European FWC analysis)**
It is obvious that only a limited number of scenarios can be calculated for all 3250+ processes. Even with a shortlist of only 20 indicators, 1 baseline and 4 scenario projections this would result in a total of 325 000 data values.	

Depending on the type of scenario analysed, different methods will be applied in the sustainability impact assessment. These will be outlined in the following sections.

4.4.1 Changing technology scenario

Innovative technology will be analysed by defining *a **new alternative production process that is characterised by a new set of indicator values***. The effect of the scenario will then be analysed by comparison of FWC A (old technology) and FWC B (new technology). This type of scenario does not necessarily change the material flow allocation between different FWCs. However, material flows downstream of the new production process may be affected due to altered efficiency of the production process and subsequent changes in product shares.

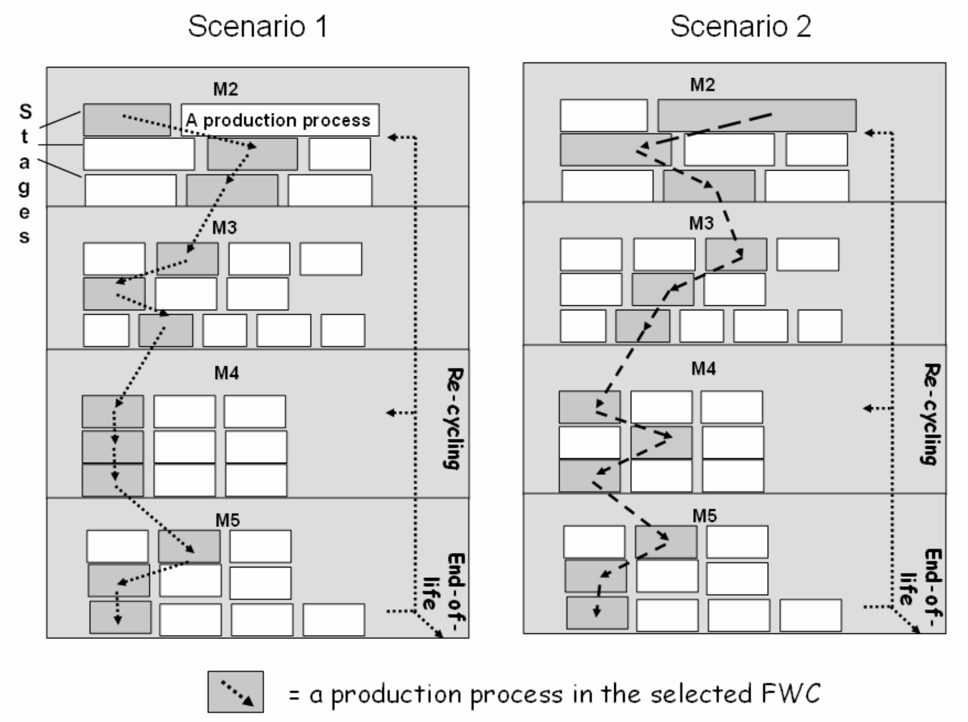


Figure 10: Changes in production technology modify the FWC and will be analysed by comparing two alternative FWC scenarios.

With the same type of scenario analysis it is also possible that the user selects two alternative production processes to compare their effect on sustainability. For example, different forest management practices could be studied as shown in Figure 11.

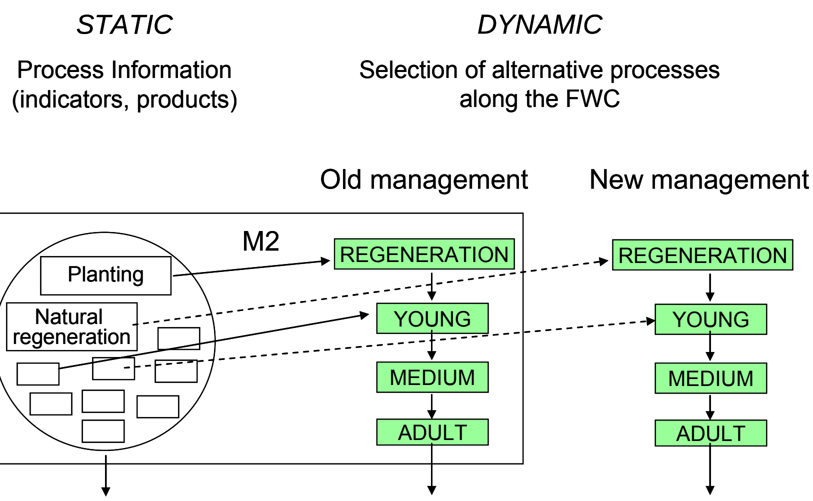


Figure 11: The user can create alternative FWCs by selecting different production processes from the static information in the EFORWOOD database. In this example two alternatives management scenarios with planting and natural regeneration are compared.

4.4.2 EU policy change scenario

EU policy changes may have different impacts with implications for the ToSIA applications. If the material flows and the structure of the FWC are not affected by the policy change, it may be sufficient to recalculate indicator values for the existing FWC processes. This will be done in ToSIA with ***response functions derived from outputs of detailed models in the Modules 2-5***.

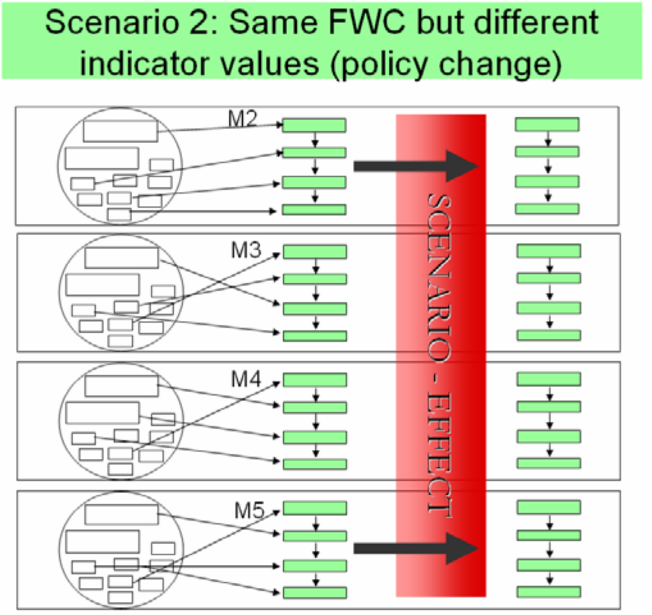


Figure 12: EU policies may influence e.g. taxation or subsidies and thereby influence indicator values for many processes along the existing FWC. The scenario effect depends on the magnitude of the policy change. Small effects may be reflected in changes in sustainability indicator values only, but larger effects often result also in changing material flows (cf. section 4.4.3).

Figure 13 gives an example of the traditional way of calculating new indicator values separately for scenarios with varying modifications of policy variables like energy taxation or subsidies. This is illustrated by two modifications of a baseline reference with scenarios involving increasing levels of subsidies. The baseline without subsidies is used as a reference to which the sustainability indicators of the two alternative scenarios are compared. This approach is not very flexible, because results can only be produced for predefined scenarios.

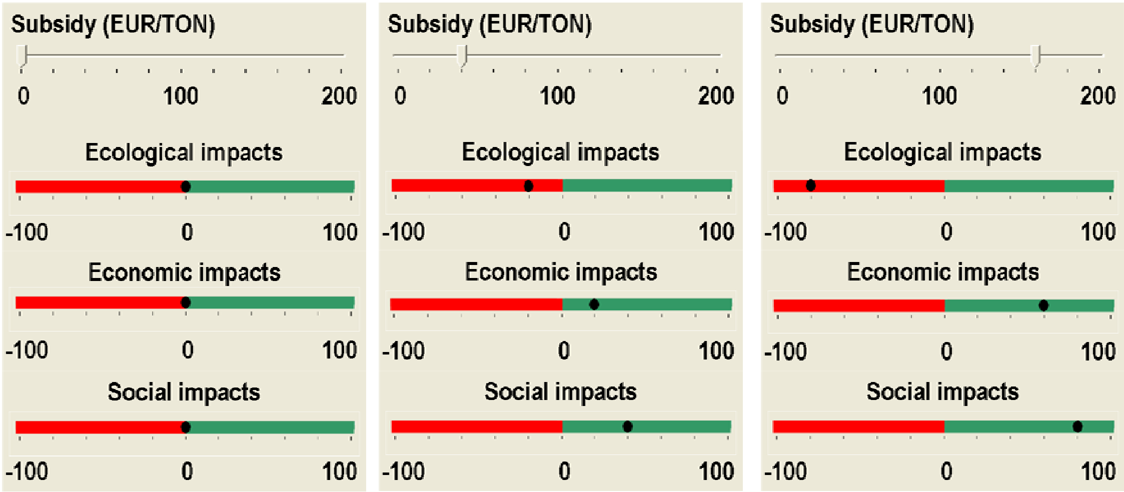


Figure 13. Comparison of three different scenarios. Left: current sustainability impacts of a baseline scenario; Center and Right: two scenarios with moderate and high subsidies result in modified ecological, economic, and social sustainability impacts (i.e., indicator values).

By introducing response functions it will be possible for the user of ToSIA to specify any level of policy change within pre-defined thresholds. The response functions will capture the effect of the policy changes on the sustainability indicators. For example in the context of an EU policy supporting generation of renewable energy a subsidy could be introduced to stimulate utilization of woody biomass from pre-commercial thinnings. ToSIA could calculate sustainability impacts of this subsidy in a range between 0 and 50 EUR per ton of biomass. This would imply that a number of scenarios with varying subsidies are calculated with the more detailed models in M2-M5 and from the results M2-M5 would calculate response functions projecting sustainability impacts depending on the amount of subsidy paid (between 0 and 50 EUR/t biomass). With low subsidies there is less change in sustainability than with higher subsidies. The response functions can have very different shapes and need not be linear (see eg. Figure 5 in pathway analysis).

In case the policy change will result in changes in material flows in addition to the change in indicator values, the procedure outlined in the next section needs to be applied.

4.4.3 Scenarios of changing global trends and EU policy change scenarios affecting the material flow and structure of the FWC

Scenarios of changing global trends and of EU policy changes which affect the material flow (and the structure) in the FWC need to be analysed in a five-step approach:

1. The market implications of global trends are analysed with the partial equilibrium forest sector model EFI-GTM. The resulting market price effects and changes in material flows in European FWC are reported to the Modules 2-5.

2. The process-specific and partial chain models applied in Modules 2-5 will analyse implications of global trends and EU policy changes on sustainability indicators and the viability of process options.
3. Changes in indicator values will be linked to ToSIA with response functions as in the previous approach. However, the response functions may be discontinuous because of changes in production technology that occur at certain sustainability thresholds.
4. Possible changes in the FWC structure will be reported from the partial chain models back to EFI-GTM and ToSIA.
5. The forest sector model will recalculate the material flows in the revised production chains and report these to ToSIA.

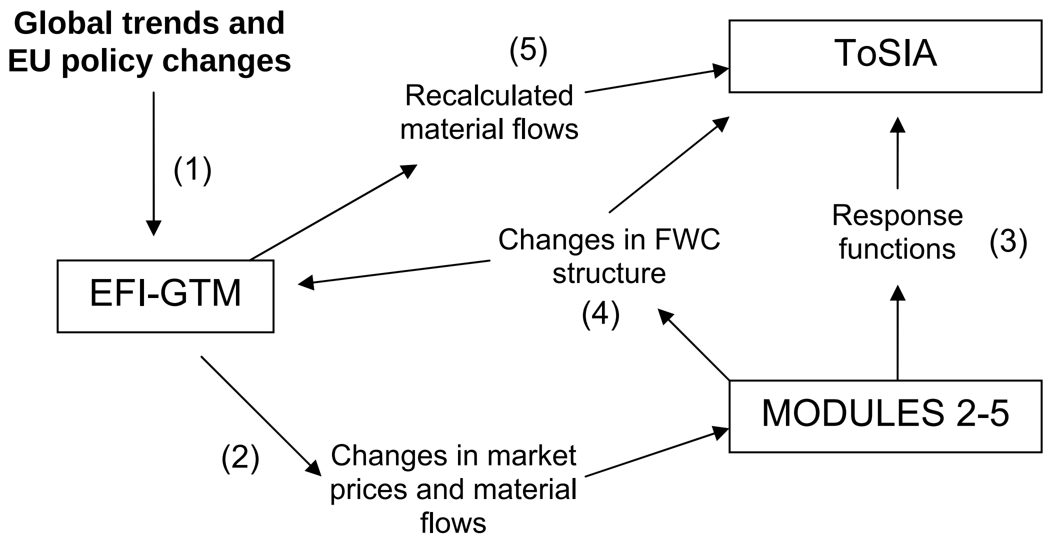


Figure 14. Flow chart representing the main steps for calculating scenarios of changing global trends and of EU policy changes which affect the material flow (and the structure) in the FWC.

4.5 Scenario evaluation with MCA / CBA

In ToSIA versions ToSIA+E and ToSIA-U it will be possible to evaluate scenario impacts on sustainability with evaluation modules utilizing MCA and CBA. The evaluation modules will be used as a supplement to a presentation of the 'raw' indicator values. The methods for MCA and CBA are currently under development and the state-of-the art are or will be reported in the internal Project Deliverable reports PD 1.5.2 (MCA) and PD1.5.1/PD 1.5.3 (CBA).

In general it is important that the evaluation methods clearly specify assumptions, weights etc. which affect the final ranking of alternatives. Therefore, simple and transparent methods have advantages. Additive MCA methods can provide a mathematically simple comparison of alternatives and this can be used as a basis for a dialogue and discussion of alternatives and criteria at the beginning of the evaluation process. Weights for different indicators should be changeable, so that the decision makers and/or stakeholders are able to view what consequences a change of weights will have on the ranking of alternatives.

4.6 Classifying and characterizing the new modelling framework

Some features of already existing tools have been considered/adopted when developing the modelling framework for sustainability assessment in ToSIA. Thus, it is worthwhile to highlight some relationships of the developed approach with the existing methods described in chapter 3:

- *FWC models*: The concept of analysing wood-material flows (based on available statistics) along national FWCs in European countries is adopted in ToSIA. This information will be relevant when considering FWCs at the European level.
- *Optimal allocation models*: In models such as WoodCIM, an integrated software for decision making at sawmills, material flow and information along the whole wood chain (considering interactions between different stages) are considered for analysing the value added to products along the chain. The system allows for analysis of different scenarios/alternatives, i.e. theoretical production lines and products, which permits studying their potential profitability. A similar exercise is conducted by ToSIA, but in addition to economic indicators/variables, social and environmental impacts are considered as well.
- *Life Cycle Assessment*: The main exercise in LCA is to obtain quantified and reliable information on the environmental impact and benefits of wood products and forestry, so that this information can be used by industry and policy makers. This is clearly adopted in ToSIA as well, expanding the exercise to the social and economic levels. LCA has been already applied to most processes along FWCs.
- *Causal Chain Analysis*: The causal link established in CCA between a proposed trade measure and a change(s) in sustainability condition(s) in the forest sector, is similar to the relationship “policy change – impact on FWC sustainability” considered in ToSIA. CCA first links changes in a trade measure to changes in incentives (prices) and opportunities (expanded market access), which can influence the production system and trade flows. Then in a second step it links changes in the production system to sustainability impacts. One can appreciate the similarities of this exercise to the scenario simulation described in chapter 4.4.3.
- SIAT (Sustainability Impact Assessment Tool of the SENSOR project): Relates policy changes to land use changes and the consequent changes in sustainability. The use of indicators and response functions in assessing sustainability impacts is very similar. However, SIAT includes only the forest resource management besides other land uses and does not consider the forest value chain. The spatial resolution is higher compared to ToSIA.
- *Pathway analysis*: The calculation of the social and environmental costs of energy in Europe by following the pathway from source emissions via quality changes of air, soil and water to physical impacts resembles the exercise of indicator calculation for FWC processes under different scenarios. The use of a detailed bottom-up methodology to calculate site-dependent external costs (cf. local effects of pollutants) is in line with the consideration of impacts at different spatial levels in both SIAT and ToSIA. This method also relies on response functions for comparing alternative scenarios.

The list of existing tools presented above and in chapter 3 documents features that partly suit for assessing the sustainability of FWCs. However, none of the existing tools addressed all three sustainability dimensions along the whole FWC in a balanced way. Consequently the development of a specific modelling framework for sustainability impact assessment of FWCs was initiated. ToSIA combines a number of elements in the methodologies mentioned above. There are three main characteristics in ToSIA:

1. Essential is the forestry-wood chain, material flow through production processes from seeds to recycling of wood-based products. This approach is known also from LCA and optimal allocation models.

2. Second characteristic is the balanced analysis of three pillars of sustainability, economic, environmental and social, - as done in SIAT and in a slightly different way also in pathway analysis.

3. Third element is the impact of changes - comparison of performance indicators of alternative production chains - as done in SIAT and causal chain analysis.

In short: ToSIA will be developed as a dynamic sustainability impact assessment model that is analysing environmental, economic, and social impacts of changes in forestry-wood production chains, using a consistent and harmonised framework from the forest to the end-of-life of final products. In the following we specify the different components of ToSIA.

The ToSIA modelling framework is based on the following components: (1) the project modules (M1-M5) of EFORWOOD, that is, the areas of expertise (researchers) in the project using specific models and data to provide information about production processes, indicator values and material flows to the database; (2) the Database, where information e.g. on sustainability indicators is stored and organised in such way that permits efficient harmonisation with the software; (3) the software, which enables dynamic interaction with users/stakeholders for defining specific FWCs and criteria on sustainability, reads sustainability information related to the defined FWCs from the database, and calculates results on sustainability for comparing the selected chains based on evaluation methods.

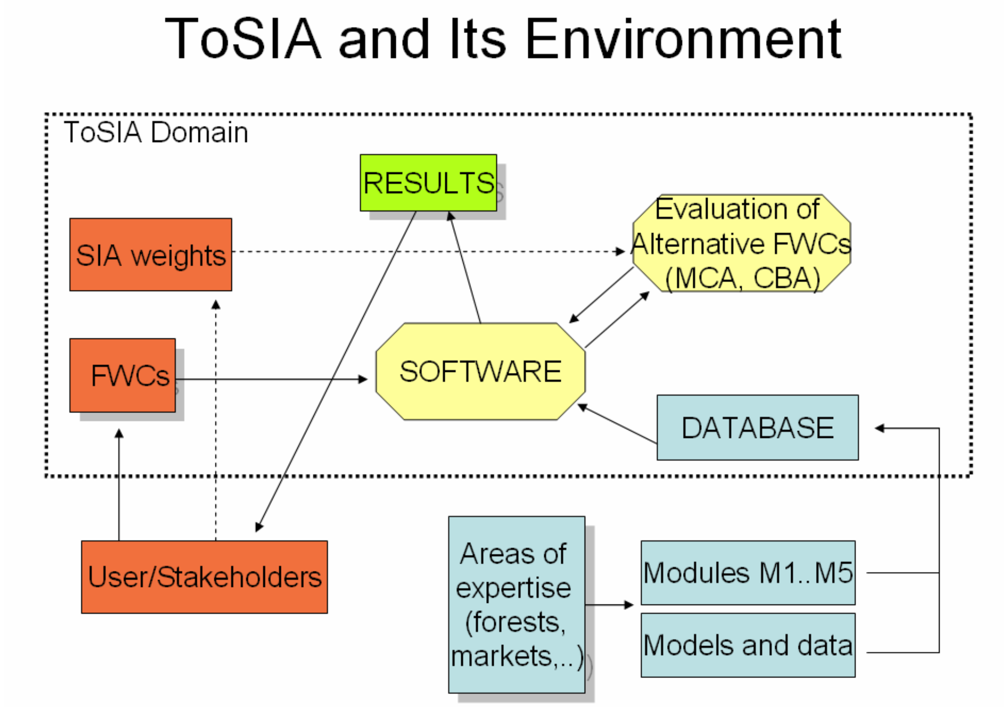


Figure 15. ToSIA and its environment: Areas of expertise (researchers) in the project provide information (e.g. indicator values) to the database, where the information is stored and organised in such way that permits efficient harmonisation with the software. Dynamic interaction (through a user friendly interface) with users/stakeholders for defining specific FWCs and criteria on sustainability is enabled by the software (heart of the system), which afterwards reads sustainability information related to the defined FWCs from the database, and calculates results on sustainability using evaluation methods, finally delivered to the user (through the interface) for comparing the selected chains.

5 Detailed description of model components

5.1 Database

5.1.1 Introduction

The data for ToSIA are stored in the EFORWOOD database developed and maintained by WP 1.2. The database contains data on processes and indicators which have been identified and quantified by different EFORWOOD modules. The database structure follows needs of the EFORWOOD project and it is primarily designed to fulfil data needs of ToSIA. Reliable ToSIA outputs require reliable input data. Therefore, data quality control represents an important part of the data gathering task in EFORWOOD. The data are coming to the database from various sources – they are submitted by numerous data collectors and originate from different statistics, research data, modelling outputs etc.

Figure 16 shows the linkage of the database to ToSIA and how data validation procedures are incorporated and linked back to the data providers. The first data check is performed when data are submitted to the database. Both completeness of the data and individual values are checked. A secondary validation of data will be performed in ToSIA by comparing output results against input data.

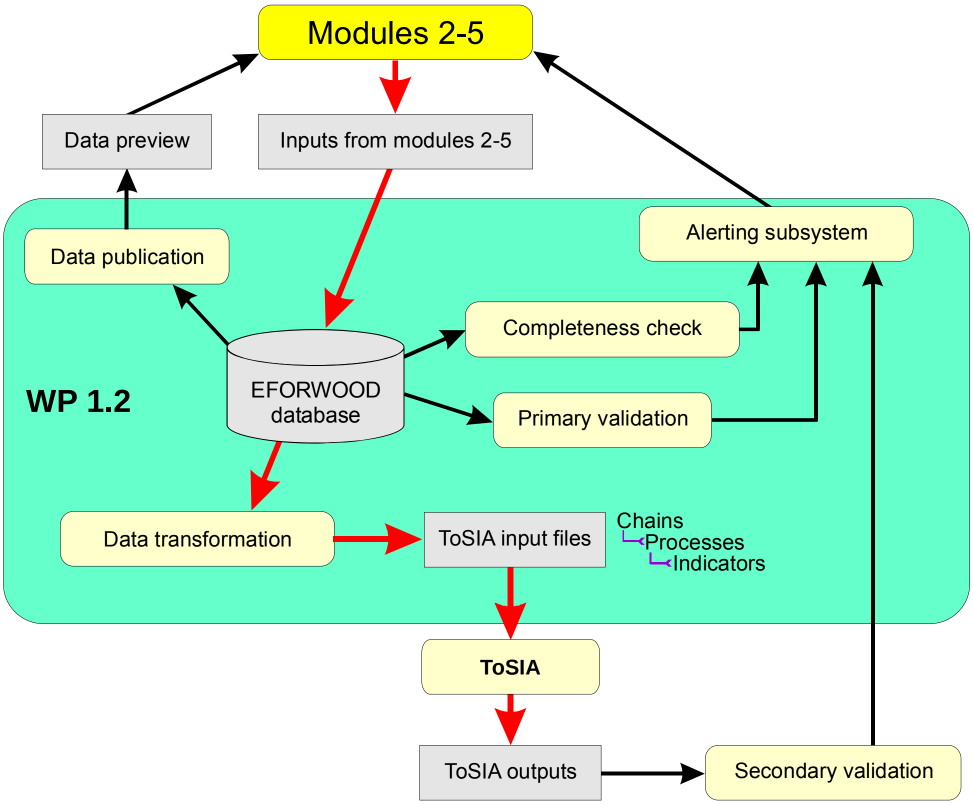


Figure 16. The EFORWOOD database collects the information from the project modules 2-5 and provides the necessary input data to run ToSIA. Data quality checks are done in several steps to secure best possible output quality of the ToSIA results.

The structure of the database is continuously developed to cover specification of processes and their products as they are formulated by modules. Together with the quantitative and qualitative data on processes and indicators the database contains metadata which describes content and quality of data.

5.1.2 Data input and output

In the first year of EFORWOOD the data collection was using Excel sheets which were filled by data collectors, delivered to WP 1.2 and transferred to the database. In the next phase of the project, an Internet-based data collection procedure will be established.

The database will be available over the internet and a special application will be used for data entering and editing. Data of individual processes and related indicators can be retrieved from the database, edited and submitted to WP 1.2. After data checking, the data will be posted to the database. Alternatively the data could be posted to the database automatically right after editing. Both alternatives will be tested and the most convenient one will be chosen for routine use. The interface between database and ToSIA will be facilitated by XML[3]

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

5.2 ToSIA Engine

5.2.1 Introduction

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

The engine will implement all the functionality related to the input data, calculation, and results that will be needed by any of the ToSIA user interface variants. This means that independent of the variant of ToSIA being used, behind the user interface there will always be the same ToSIA engine – just dressed up in different interfaces for different purposes. In designing the user interface, the developer can choose to use the needed functionality from those available in the engine. The user interface defines which of the engine's functionalities will be available to the user of the software.

The most central aspect of the engine is the calculations it performs, and these will be presented in more detail in subchapter 5.2.3.

5.2.2 ToSIA input data and data structure in ToSIA

As seen in Figure 15 and Figure 16, ToSIA receives its input data from the EFORWOOD database. Input is also provided by the user of the software. The user's input is composed of commands given via the user interface and by possible manual revision of data or entry of new data. Some of the user's commands will affect the engine, and some will be pertinent only to the user interface itself. The given information implies that the engine will have a programming interface of some kind which provides the user interface the group of functionality offered by the engine.

Data from the database is loaded into ToSIA when the application is started. This data must follow some agreed-upon format, in order to be processable by a machine. The actual input to ToSIA is an xml-file, the content of which must adhere to an XML schema defined by a separate XSD-file[4]. The application will proceed to parse the contents of xml-files into its internal memory structure.

The data derived from the database that is input into ToSIA forms two groups:

a) "Static data" which has been gathered through work done in the EFORWOOD project. This is data on processes, products of processes and indicator effects of processes in units per mass (or units per ha for M2 processes). This data is in most cases not altered during the use of the application.
b) "Dynamic data" which is data that defines the chain structure of FWCs. This information also includes definition of which products flow in each linkage between two processes. This data originates also from the work of the EFORWOOD project, but this data can be edited by the user – for example to create a new customized FWC based on available static data, but optimized to suit a user's particular need.

The idea of static data can perhaps best be represented by saying that it is an unordered group of data on processes, grouped by module and stage of FWC. Dynamic data is formed by picking processes from static data, and putting them in a structure which links processes, and for each link defines the product flowing between two processes. The internal data structure used for organizing the dynamic data inside ToSIA is essentially **a directed graph[5]**. A directed graph is depicted in the Figure 17.

[4] XSD – XML Schema Definition; XML Schemas express shared vocabularies and allow machines to carry out rules made by people. They provide a means for defining the structure, content and semantics of XML documents. For more information please see http://www.w3.org/XML/Schema

[5] For more information on the concept of a directed graph: http://en.wikipedia.org/wiki/Graph_%28mathematics%29#Directed_graph

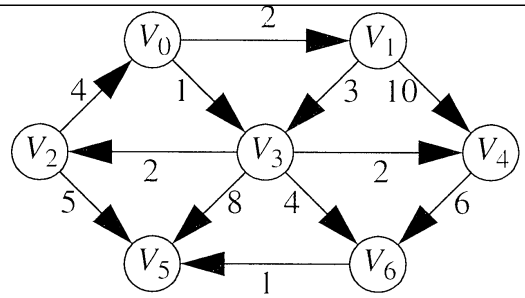


Figure 17: A weighted, directed graph (cf. Weiss 1998). The vertices (V) are analoguous to processes in the FWC, while the arrows in this graph are edges, which are analoguous to the links between FWC processes.

Directed graphs are composed of vertices and edges, which relate to the processes (vertices) and the links between them (edges); in the attached illustration the vertices are denoted by "V_n" and the edges are denoted by the arrows connecting vertices. The attached figure also shows weights for the edges. Though the amount of flow from process to process in ToSIA could be seen as a kind of a weight, the analogy is not accurate as the amount of flow does not correspond with the concept of weighted edges, where the weight represents the "cost" of traversing that edge. Therefore the concept of a weighted directed graph does not apply here. However, it should be emphasized that due to e.g. recycling loops in paper processing the graph is not acyclic (and cannot be considered a tree-structure).

For more information on the ToSIA input data format, please refer to the earlier deliverable PD 1.4.2. Output from ToSIA follows similar formatting, but also includes the results in various different forms. The details of ToSIA output format can be found in PD1.4.4.

5.2.3 Description of calculations within the ToSIA model

The ToSIA sustainability calculation proceeds as follows:

1. Data is read into ToSIA from the EFORWOOD database. In the first prototype this is done from two xml-files. First the static information of the available processes is loaded. This info is grouped into modules and contains the stage inside the module, georeference, etc. as metadata.
2. The second xml-file containing the definition of the shapes of the different FWCs is read in. The chain-structures are built using the static process information previously read in.
3. Once the shapes of the FWCs are established, the material flows along the FWC are calculated using an initialisation flow on the M2/M3 boundary. The flows of material which stream through subsequent processes are calculated based on product shares stored with the static process information.
4. Sustainability indicators are calculated for all processes. Indicator values in the EFORWOOD database are stored per unit of material flow. Sustainability indicator results per process are calculated by multiplying the material amounts flowing through the process with the indicator value per unit of

material. The result is the sustainability indicator effect for the individual production processes (Figure 18).

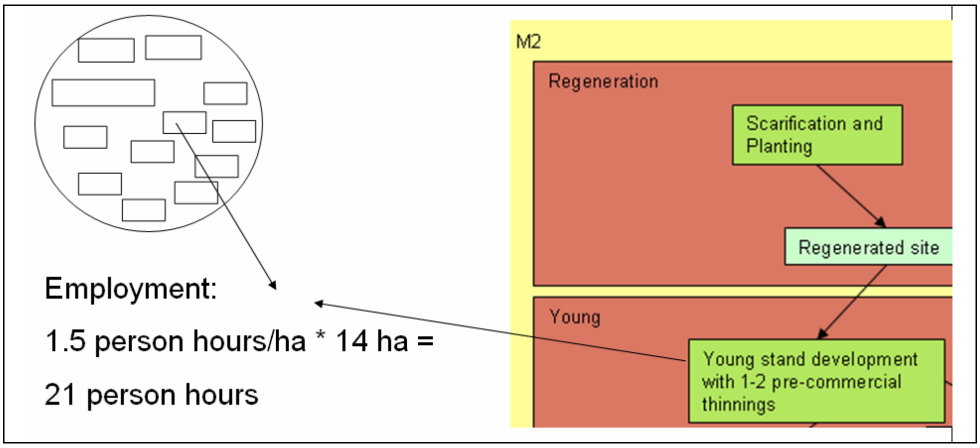


Figure 18: Calculation of indicator values in each process. Indicator values per unit of reference flow are taken from the static information in ToSIA and multiplied with material flow in the selected dynamic chain to obtain the sustainability indicator value for the process.

5. Indicator results are aggregated with arithmetic operations. Aggregation types differ between indicators. For some indicators (e.g. emissions to air, employment) it makes sense to calculate the sum of the process results regarding the indicator along the FWC (Figure 19). Others need to be processed in different ways (averaging or more complex calculations). Furthermore, aggregation will be implemented in ToSIA as vertical chain-based aggregation and horizontal module- or stage-based aggregation. Also metadata such as spatial information can be used as an aggregation criterion in the aggregation process.

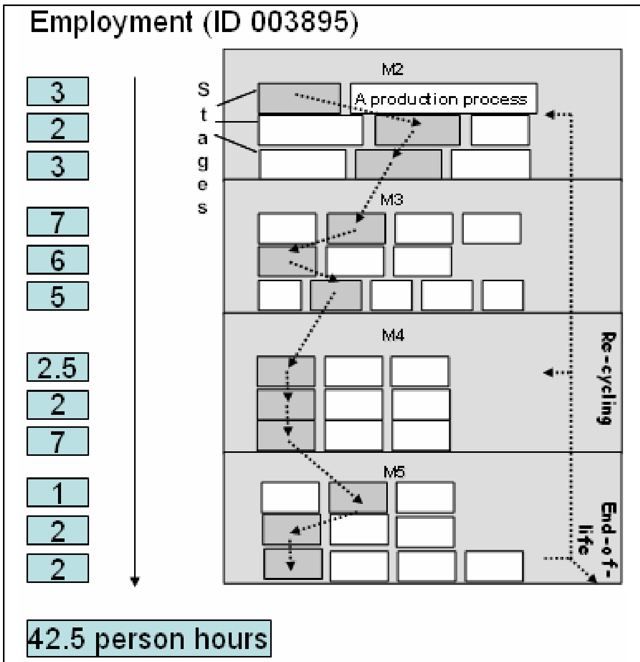


Figure 19: Aggregation of indicator values along the forest wood chain. For aggregating the indicator values the system takes the indicator ID (in this example employment) and identifies indicator values for different processes in the calculated chain. After this indicator values of the same ID are summed up (if adding up makes sense).

5.2.4 Flow calculation in some detail

In the first prototype, the algorithmically most complex calculation is the method for dynamically calculating the material flows in a chain.

The key assumptions of flow calculation in the first prototype are:

- the output product shares are known, they define the amount of material flow into each consecutive process.
- There is no control on the process' inputs and outputs (e.g. in form of a mass balance as this is normally the case in LCA tools). They are assumed correct both in amounts relative to each other and consistency
- If the FWC contains loop-structure (e.g. recycling loops), the process receiving the result of the loop as input must ALWAYS have at least one other input source
- FWCs with loops inside loops are not allowed

One of the more difficult things to calculate is the input material flows provided by the loop-structures within the chains. Only infinite loops are allowed, i.e. such loops whose "cycle times" are unbounded. Next a brief mathematical overview of the calculation of the loops in ToSIA is given.

Calculating the loop is essentially calculating a mathematical series[6], the sum of which converges toward a finite limit as n approaches infinity. The limit is the answer to the question of how much output does the ROOT (the process receiving the output of a loop as input) provide. If desired, the input given by a process to ROOT can simply be calculated from this result. The PATHSHARE is the proportion of ROOT's output that the final process in the loop gives as output, passing it to ROOT as input. The behavior of the mathematical series can be described with the formula:

$$\sum_{n=0}^{\infty} P^n (A + B + ...Z)$$ ***Where,***

A..Z are the different amounts of flow into ROOT, not counting the recycling loop itself
P is PATHSHARE
P^n is ≤1

However, this explanation of behaviour can be better calculated by using the following equation derived from the previous one. With the effect of n eliminated, it enables more exact and efficient calculation. The total output of ROOT can be calculated using the following function:

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

A..Z are the different amounts of flow into ROOT, not counting the recycling loop itself
P is PATHSHARE

[6] (http://en.wikipedia.org/wiki/Mathematical_series)

5.2.5 Indicator value calculation in some detail

After calculation of flows ToSIA needs to calculate the actual indicator effects. Each process has at this stage a group of indicators expressed on a value per material flow basis and the actual realised material flow. Calculating the indicator effects in the first prototype is done by multiplying the material flow with each of the process' indicators.

Total FLOW * (relative indicator value per unit of FLOW) = absolute indicator value

At a later phase in ToSIA development, when response functions will be employed to describe indicator behaviour, the calculation will be somewhat more complex. However, even then there will only be the additional step of identifying the right point along the response curve and then proceeding with calculation as in the prototype with multiplication with flow.

5.3 MCA and CBA Evaluation modules

Data transfer formats from indicator-calculation to evaluation modules

The data transfer procedure depends to some extent on the general EFORWOOD database structures, which are currently under revision after the first data collection experiences. There are several options: (1) a common ToSIA database where all static and dynamic information is stored as well as the aggregated indicator values once ToSIA has been run. CBA and MCA can access this data base for their calculations and store their output in it (see Figure 19). (2) as (1) but CBA and MCA both store their output (and analysis settings) each in a data base of their own. (3) no data base for output from ToSIA indicator aggregation, results are produced on the fly, MCA and CBA each have their own data base to store the respective outputs. In any case no commercial software can be used due to the limitations on this in the EFORWOOD-project.

The MCA module

Two variants for the MCA module component are currently under consideration: (a) a single user version, and (b) a group decision making variant.
The single user version is the base variant. It sees a single user operating the software tool. No stakeholders are present during the evaluation session. The decision maker / the analyst wants to explore effects of different preference profiles (i.e., scenario settings with regard to archetype stakeholder preferences, etc.) on the ranking of alternative FWCs. Prefabricated preference information (i.e., weightings of indicators, preference functions for indicator values, etc.) is available in the data base and can be called by the single user. The user may interactively try/adapt/modify the preference information and test the effect on the preferability of alternative FWCs to learn about strengths and weaknesses of different FWCs. Figure 20 shows the schematic flow of this procedure.

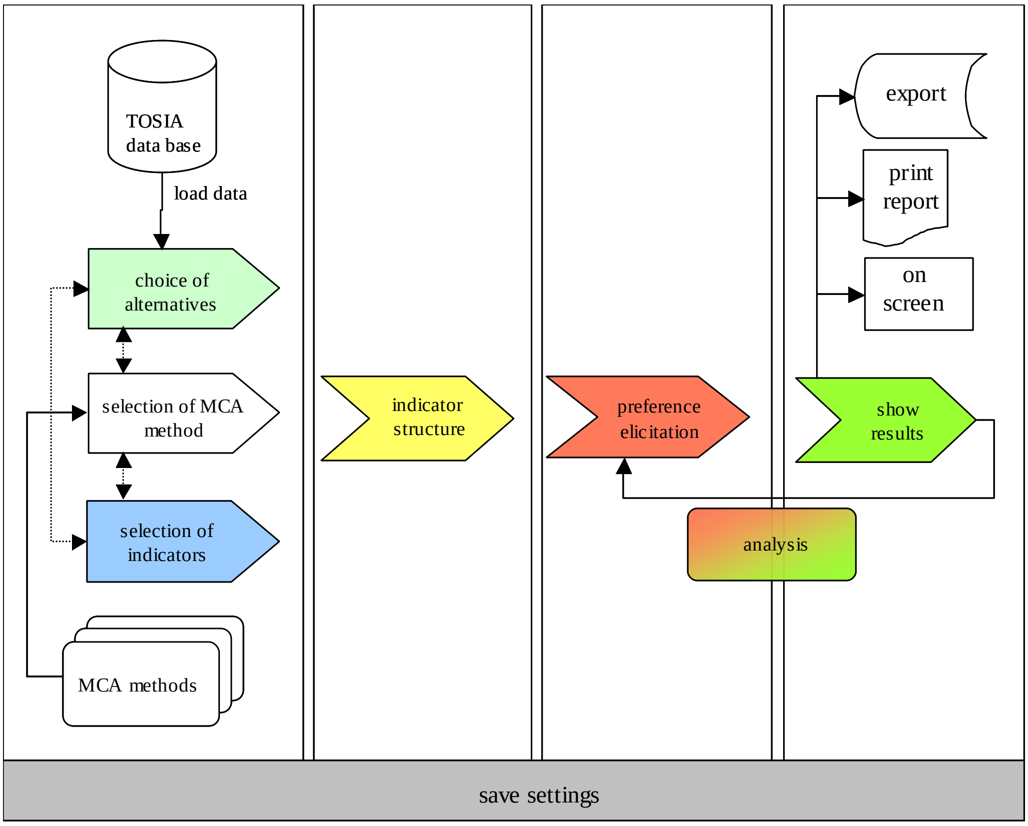


Figure 20. Schematic flow of a session in the single user variant of the MCA component.

The group decision making variant allows stakeholders being part of the evaluation session either via intranet, on site, or via the World Wide Web. The session is guided by a master user (i.e., moderator). She guides the group through the phases of a MCA session: (a) selection of indicators, (b) elicitation of individual preferences, (c) comparison of individually generated results anonymously or not, (d) check for similarities and compromise solutions.

5.4 User interface

The introduction to ToSIA engine in chapter 5.2.1 already discussed the division of work between the engine and the user interface. The functions that will be provided by different variants of ToSIA will require somewhat different user interfaces, but the specifics of these interfaces have not been defined yet.

Design of the user interface is the most important component, when trying to make a software intuitive to use. For example, in chapter 1.3 it is stated that:” ToSIA-U is a user-friendly version including a graphical user interface and context-help allowing fast learning and application of the tool”. For the users to be able to achieve their goals, studies need to be conducted to gather user requirements and map expectations.

5.5 The forest sector model EFI-GTM

EFI-GTM is a regionalised, global, partial equilibrium model which incorporates forestry (as wood and fibre supplier through harvest) and forest industries (as consumer of wood fibre) having 60 regions (Europe is divided in 32 regions which correspond mostly to countries, and the rest of the world in 28 regions). Partial equilibrium means that the model balances supply and demand for each round-wood assortment and forest industry product in each region taking into account export and import between each of the regions. Thus production quantities and prices (as well as net import/export) are determined endogenously in the model for each round-wood assortment and forest industry product in each region. The model ensures that demand equals supply for each year, product, and region, including import /export possibilities. The model is at present recursive-dynamic.

For each region the model will include a forestry model, six types of round wood harvest assortments, and 26 types of forest industry products, all of which are integrated through trade and specified with respect to production costs and capacities for each region. For each of the European regions each forest industry production is characterized by three existing technology vintages – high, medium, low costs and one or more new alternative technology vintages, which will be introduced in the future through new capacity expansion. New investments in forest industry capacities take place if the present price of the respective product covers variable production costs and annual costs for the new investments. For each region, forest product and technological vintage - variable production costs are defined through labour, wood, energy input per unit of product and other costs. Round wood supply in each region is influenced by the forest growing stock (which is determined by growing stock at starting time, annual harvest and annual forest growth).

EFI-GTM model will be used for assessing how, through trade and demand & supply interactions, specific production changes in the European FWC will influence other production activities in that chain and in regions outside Europe (in particular developing countries), and also how changes in these latter regions may influence the European FWC. The model will also be used for assessing the effect of possible policies aimed at the FWC through for example taxes. Policy instruments like taxation or subsidies can easily be introduced in the model as exogenous factors, increasing (respectively reducing) costs, and the model will adjust supply and demand as well as trade balances accordingly. Global trends or changes in EU policies will result in regional wood harvest and forest industries production and price changes, which will be reported to ToSIA through response functions (see Figure 14).

A more detailed description of EFI-GTM can be found in PD 1.3.1.

5.6 Policy database for ToSIA

The database will contain all current EU and international legislation and policies that affect the sustainability of the FWC, based on the systematic framework of SI indicators and institutional indicators. It will also contain technical standards and norms as far as necessary. The objective of the database is to link policy documents or paragraphs in policy documents to sustainability indicators and changes in them. The information will be utilized as one basis for selecting scenarios for the analysis in EFORWOOD. Moreover, it will be instrumental for the interpretation of ToSIA runs. Existing thresholds for sustainability indicators will be identified.

Structure of the database:

A) DOCUMENT:
All relevant documents (legislation and policy documents) are stored in the database. The documents are classified according to the following criteria:

- Status (in force or not in force)
- Type of legislation (i.e. decision, regulation, directive, etc.)
- Type of policy document (i.e. action programme, action plan, working programme, implementation report, policy strategy, etc.)
- Organisation (that issued the document)
- Year (when the document was issued)
- Geographical scope (i.e. global, European, national, provincial, municipal)
- Date of inclusion
- Inclusion by whom (author)
- The document itself
- Reference number of the document

B) INDICATORS
The database contains a list of indicators. Here all indicator names (see D 1.1.1) are stored. The indicator classes, subclasses as well as those indicators that have been selected for ToSIA applications are stored in the database;

C) INDICATOR USE
Furthermore the database provides some information on the indicator use. The list shows which indicators, respectively which sub classes and ToSIA class have been referred to by which document.

D) TARGET / THRESHOLD
The database shows all targets and thresholds that have been found in the relevant international and Europan legislation and policy documents. The Targets and thresholds are classified according to the following criteria:

- Text (full text of the target/ threshold)
- Type (i.e. legally binding, non-legally binding)
- Form (quantitative, quantifiable, non-quantifiable)
- Quantitative target (include the number of the original text with the measurement unit and the time reference if given)
- In the case of a quantifiable target (increase, decrease, maintain)
- Comments (on the target settings if necessary)
- Indicator
- Indicator class
- Indicator subclass

The policy database will be documented in more detail in deliverable report D 1.1.3.

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ANNEX 1 Implementation of first ToSIA – Prototype

This section describes in brief the structure of the first prototype version of ToSIA. The software contains just one package: `tosia.engine`. This package contains 15 files, each corresponding to a class. Two of these classes are currently just placeholders, others contain implementation and are in use. The classes are by no means complete yet, they contain only the functionality needed to perform the current tasks. Some excess functionality left over from the development period's gradual progress has not yet been removed because they might prove useful in future development.

The Action class is the command prompt, which starts actions implemented in the other classes according to a user's commands. However, starting ToSIA also creates an empty ModuleSpace and ChainSpace – they are later filled in by the user’s commands. Reading in both are required for running the program. A special care should be used, for there is absolutely no error management in the prototype.

The classes that make up the prototype are the following:

Action – this is the Main class that contains the command prompt that starts all other functionality.
Analysis – this is currently unused.
CalculatedIndicator – each instance holds one calculated indicator value.
ChainSpace – container for all chains in current work space.
ConversionFactor - each instance contains one conversion factor. At current this information is parsed from xml, stored and ready to be used, but because of the lack of actual data, the use of this information is still not programmed.
FlowItem - flow is either dynamically calculated or in some cases can be read in from xml-files. Initialization flows are an example of flows which are read in from static data.
IndicatorValuePerMaterialFlow - each instance of this is used to store one indicator value per material flow. These are stored in a Vector inside Process.
LinkToProcess - this is the key ingredient of building chain structures. This is what the chains are made up of. Contains all the necessary references to preceding and following LTPs and also points to the Process-object it is representing in the chain structure.
Module - is mostly a structure without significant functionality, except for what is needed to add, remove, and search for processes belonging to this module.
ModuleSpace - this is the container for all static data loaded from xml. It also has the tools needed for parsing the xml file containing all the static information such as modules and processes.
Multiplier – this is currently unused.
Process - A process is an object inside which all the information concerning a single process is stored. When building chain-like structures the LinkToProcess is used as a reference to the process. This way one process-object can participate in many chains.
ProcessChain - this is the data structure of a FWC. This is a collection of LinkToProcess-objects, which are stored without regard to their order. The LTPs themselves contain the information of their relative order. This class also contains the tools needed for building the chain shape from xml data.

Product - this used for storage of product information. Stores also a vector of conversionFactors-objects. Contains the functionality necessary for setting and getting values belonging to product.

ValueObject - This class is not for use by itself, but for storage of more specific instances of values by means of inheriting this class. As such, contains only tools for setting and getting its fields.

For more detailed documentation of the implementation of this prototype, see the Javadoc html-documentation files. These can be accessed by opening the file: `./javadoc/index.html` in a web browser (the given path is relative to the place where the ToSIA prototype is stored).

The Prototype version attached to this document for internal EFORWOOD review includes simplified Flow calculations. Due to incomplete conversion factors for conversion of material flow information from m3 to organic carbon content, the flow calculation is currently not yet implemented based on the carbon content; m3 flows are used for the Modules 3-5 instead. The conversion factors are currently under review and will be added in the next phase, when Single FWC data are analysed with ToSIA.

ANNEX 2 Quick guide to running the ToSIA – Prototype

As there is no error checking present in the prototype, it is assumed that the program will crash or work incorrectly in all situations which deviate from the intended actions or order of actions.

Prerequisites:

- the Java runtime engine (JRE) version that was used in producing the prototype was 1.5.0_07 (Java(TM) 2 Runtime Environment, Standard Edition (build 1.5.0_07-b03)). Optimally, the version should be this or newer – the version can be checked by giving the command: `java -version` at a command prompt.
- The files `test_module.xml` and `test_chain.xml` should be located in the same directory as the executable (`tosia2006_nb.jar`).

To start ToSIA:

In Windows: open the command prompt (Run – and type "cmd"), change to the directory where ToSIA is located (e.g. "cd tosia1") and give the following command:

```
java -jar tosia2006_nb.jar
```

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

a) **c** - to list contents of chains
b) **m** - to list contents of all modules
c) **x** - to load modules from xml
d) **y** - to load chains from xml
e) **e** - to end running ToSIA
f) **h** - to read this listing of commands
g) **p** – calculate and print to screen results of Pine Chain
h) **s** - to calculate and print to screen results of Spruce Chain
i) **u** - to calculate and print to screen results of Eucalyptus Chain

The modules must be loaded before the chains can be loaded, otherwise the program will malfunction. Once information has been loaded it cannot currently be removed. This can be accomplished by exiting and restarting the program.